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MINUTES AND PROCEEDINGS

of the twenty-fourth meeting of the

ARMED FORCES - NRC VISION COMMITTEE

November 14-15, 1949

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BY Robert H. Stewart DATE June 25, 74
Actg Phys. Sec. Officer, NIA

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AUTH	Memo Ex Secy NRC Vision
DATE	Committee 9 Dec 53
SECURITY OFFICER	
Frank B Rogers, Roldre	

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Minutes of the Twenty-fourth Meeting

November 14-15, 1949School of Aviation Medicine and Research
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Sunday, November 13, 1949

Page No.

1. The Subcommittee on Visual Standards met to consider the sample near and far acuity test charts prepared in accordance with Subcommittee recommendations, and to hear a progress report of research on visual acuity conducted by Dr. Louise Sloan. A report of the discussion of the Subcommittee may be found in the Proceedings. 21
2. The Subcommittee on Visual Displays met to review the pamphlet entitled "Standards to be employed in research on visual displays" published by the Vision Committee in October, 1947, and to discuss the possibility that recommendations for design and construction of certain visual displays may now be made. The Subcommittee met also during the morning of November 14. A report of the two Subcommittee meetings is contained in the Proceedings 27
3. The Subcommittee on Visibility and Atmospheric Optics considered the relevance of recent visibility research results to meteorology. A summary of the discussion is contained in the Proceedings 31

Monday, November 14, 1949

4. The Subcommittee on Visibility and Atmospheric Optics met to consider progress in the various research projects being conducted in the areas of visibility and atmospheric optics. The following progress reports were considered:
 - a. Dr. Howard S. Coleman presented a progress report on the studies of atmospheric optics at the University of Texas. 35
 - b. Dr. Richard Tousey presented a progress report of recent "Measurements of Atmospheric Transmission Across Chesapeake Bay" 41
 - c. Dr. E. O. Hulburt presented a paper entitled "Atmospheric Attenuation for Wavelengths 2500 - 10,000 Angstroms" 45
 - d. Dr. E. O. Hulburt presented a paper prepared by Dr. H. S. Stewart entitled "The Determination of Slant Visibility". 47
 - e. Dr. H. Richard Blackwell reported that the studies undertaken at Roscommon and Akron have been completed and the facilities dismantled. He reported that final data analysis is under way.
 - f. Dr. R. A. Woodson reported two studies undertaken by the Aero Measurements Laboratory, Northwestern Technological Institute, concerning the visibility of two kinds of targets. The research reports are

classified, and, therefore, are not included in the Proceedings of the present meeting.

g. Dr. S. Q. Duntley reported briefly the status of the research undertaken at Diamond Island, New Hampshire. He reported that final equipment was nearing completion and that it was hoped the data collection could be completed before winter weather closed in upon the Island.

h. Dr. H. W. Rose presented a paper entitled "Photometric Survey of Working Conditions for Night Visibility Determinations at Airports"

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THE SUBCOMMITTEE WISHES TO EXPRESS ITS SINCERE THANKS TO COLONEL VICTOR A. BYRNES FOR AUTHORIZING THE SURVEY UNDERTAKEN BY DR. ROSE. THE SURVEY WAS REQUESTED BY THE SUBCOMMITTEE ON VISIBILITY AND ATMOSPHERIC OPTICS IN CONNECTION WITH SOLUTION OF PROBLEMS CONCERNING METEOROLOGICAL OBSERVATIONS AT NIGHT.

5. The Working Group on Sunglasses considered the following items:

a. Dr. R. H. Peckham presented a paper entitled "The Specification of Sunglasses" 53

b. The Working Group considered a request received from the Bureau of Medicine and Surgery concerning sunglasses for use by Navy flying personnel, and also requests from the Quartermaster General of the Army concerning the use of polarizing lenses and clip-on attachments as general issue sunglasses. A discussion of these requests for information is contained in the Proceedings. 61

6. A tour of the School of Aviation Medicine and Research was arranged.

7. The Chairman of the Vision Committee, Dr. Richard G. Scobee, called the meeting of the main Vision Committee to order. He asked if there were corrections or alterations in the Minutes of the 23rd meeting; there were no corrections.

8. Captain Wilbur E. Kellum, Senior Medical Officer of the Pensacola Naval Air Base, welcomed the Vision Committee to the Naval Air Base and to the School of Aviation Medicine and Research.

9. Lt. Comdr. Henry A. Imis presented a paper entitled "Research in Vision Related to Disorientation" 65

10. Dr. Kenneth N. Ogle presented a paper entitled "A New Aspect of the Fusional Processes in Binocular Single Vision" 71

11. Dr. Alphonse Chapanis presented a paper entitled "The Effect of Training on Color Vision Defects". 79
12. Mr. John A. Watson presented a paper entitled "Preliminary Report of Test Methods for Determining Resolution, Scale, and Contrast Requirements for the Detection and Recognition of Objects on Aerial Photographic Negatives". 83
13. Lt. Comdr. Dean Farsworth presented a paper reporting further studies of equated Snellen type letters for use in acuity test charts. 87
14. Mr. Fred R. Brown presented a paper entitled "Visual Problems in Designing Improved Indirect Lighting for Aircraft Cockpits". 93
15. Dr. Ingeborg Schmidt presented a paper entitled "Further Study of the Effect of Illumination on the Interpretation of Pseudoisochromatic Plates". 103
16. Dr. David Freeman asked that the report of the June 9, 1949, meeting of the Subcommittee on Visual Standards be read into the Minutes and Proceedings of the present meeting . . . 107

Dr. David Freeman reported the activities of the Subcommittee on Visual Standards in preparing a new Armed Forces Visual Acuity Chart for far and also for near vision and in considering a research procedure designed by Dr. Louise Sloan for the study of visual acuity test slides in the Orthorater. The full report of the Subcommittee meeting is included in the Proceedings (p. 27) Discussion of the Subcommittee report is included in the Proceedings 118

Dr. Freeman proposed, and the Vision Committee approved, the following recommendation:

In view of the fact that small differences in visual acuity of the same individual will undoubtedly appear when he is tested on the presently used Snellen chart and on the new chart, it is strongly urged that the three military departments issue a directive coincident with the distribution of the new chart specifying that it alone be used.

17. Dr. E. O. Hulburt reported on the meeting of the Subcommittee on Visibility and Atmospheric Optics. The full report of the Subcommittee meeting is included in the Proceedings (p. 31)
18. Dr. Donald G. Marquis presented a report of the Working Group on Sunglasses. The full report of the working group meeting is included in the Proceedings (p. 61)
19. The following recommendations of the Working Group on Sunglasses were approved by the Vision Committee for submission to the

appropriate military authorities:

- A. In response to a request from the Bureau of Medicine and Surgery of the Navy, the Subcommittee prepared the following recommendation concerning sunglasses for use by flying personnel:

The Navy neutral sunglass N-4 is satisfactory for the use of flying personnel. Colored sunglasses (green, amber, rose-smoke, Calobar) are less satisfactory for general use. It is to be noted that sunglasses with special spectral selectivity may have special uses. Uniform or gradient density coatings are acceptable for special purposes, but have no general value. The sunglass E8314 made by Bausch and Lomb, which is claimed to be a satisfactory neutral and yet to provide contrast enhancement, is not considered satisfactory either as a neutral or as a contrast enhancing sunglass. It is considered that no further testing is needed at present to determine satisfactory sunglasses for general flying use.

- B. In response to a request received from the Quartermaster General of the Army, the Working Group prepared the following recommendation concerning the use of polarizing lenses for general issue sunglasses:

Polarizing lenses do not offer sufficient advantages over non-polarizing lenses to warrant general issue but may be desirable for specialized uses involving polarized light from snow or water.

- C. In response to a request from the Quartermaster General of the Army, the Working Group prepared the following recommendations concerning the use of clip-on sunglasses for supply to personnel wearing ophthalmic correction lenses:

It is recommended that, when it is impossible to supply tinted ground lenses, clip-on sunglasses are considered acceptable. It is recognized that the clip-on sunglass is not a completely satisfactory solution to the problem because the peripheral visual field is not protected by clip-on sunglasses. General issue sunglasses should be made of glass of suitable quality until a more satisfactory neutral gray, hard-surface plastic is available. Power distortion should not exceed 1/8 diopter; visual transmission shall be 8 to 15%; the glass shall be essentially non-selective in transmission.

20. Dr. Walter F. Grether presented the report of the Subcommittee on Visual Displays. The full report of the Subcommittee meeting is included in the Proceedings (p. 27)

Tuesday, November 15, 1949

21. Members of the Vision Committee spent the day aboard the aircraft carrier, the USS Cabot, which was operating off the coast of Pensacola in a pilot training maneuver. A brief description of the day's events is contained in the Proceedings.

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* * * * *

ABSTRACTS.

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MEETING OF THE SUBCOMMITTEE ON VISUAL STANDARDS

The Subcommittee met at 8:00 p.m. on 13 November 1949. Those present at the meeting were:

Dr. Richard G. Scobee, Chairman
Col. Victor A. Byrnes
Captain O. Chenault, USN
Dr. David A. Freeman
Dr. Hedwig Kuhn
Col. Austin A. Lowrey
Dr. Donald G. Marquis
Dr. John A. Matthews
Dr. Kenneth N. Ogle
Dr. William Rowland
Dr. Ingeborg Schmidt
Dr. Louise Sloan
Dr. Julius Uhlaner
Dr. F. E. Washer
Dr. Benjamin Wolpaw

Dr. Scobee opened the meeting by calling for discussion of the sample near and distance visual acuity charts prepared by the Vision Committee Secretariat in accordance with specifications prepared by the Subcommittee in its meeting on June 9, 1949. Dr. Scobee reminded the Subcommittee that discussion should center around specific changes in construction and design with a view to instructing the draftsman so that he might prepare the final sample charts. Dr. Scobee commented that the chart had been designed primarily for use in clinical testing.

The present form of the sample near and far acuity charts are presented in the following figures: Figure 1 presents the low acuity side of the far chart. Figure 2 presents the high acuity side of the far chart. Figure 3 presents the acuity side of the near acuity chart and Figure 4 presents the reading card side of the near chart.

The following recommendations were made by the Subcommittee for changes in the sample far chart:

(1) Since maximum legibility is more nearly obtained when the distance between letters is equal to the width of a letter, the letters should be re-separated as follows:

(a) In Figure 2, lines 5-11 should have an increase in the separation between the fifth and sixth letter in the amount of ten millimeters. This will make a total of 30 millimeters separation between these letters.

(b) The initial letter in line 5 in Figure 2 is to be at least 1 letter width from the numeral designating the line.

(c) There is to be exact vertical alignment of all letters in lines 5-11 in Figure 2 so that all the initial letters in lines 5-11 will be removed from the designating numerals by one width of a 20/25 letter. The exact vertical alignment of letters will permit the examiner to ask the patient to read either horizontally or vertically as desired.

(2) The visual angle and visual efficiency designators are to be moved up and down respectively so that they are separated by the letter height and so that a

blank space is left at the end of each line.

(3) At the left end of each line, the Snellen designation is to be placed under the numeral designating the line rather than under the first letter in the line.

(4) Numerals designating the lines shall be printed in bright red in the same size used in the present samples.

(5) The following instructions are to be printed in small type at the bottom of Figure 2. "To score visual acuity: (a) all test scores are to be recorded in round numbers; that is, 20/20, 20/40, not 20/20 / 2 or 20/40 - 3, (b) for a score of 20/200 or ten minutes, both letters must be read correctly, (c) for a score of 20/100 or 5 minutes, 3 out of 4 letters must be read correctly, (d) for a score of 20/40, 6 out of 8 letters must be read correctly, (e) for all other scores, 7 out of 10 letters must be read correctly."

(6) The visual angle notations are each to be divided by 5. Each refers to the over-all size of letters rather than the width of the stroke.

(7) The far charts are to be printed both as one page charts and as cut and hinged charts, the hinges to be white.

(8) The chart is to have a metal rimmed eyelet at the top center, 1/4 inch from the edge.

(9) The chart is to be 28 x 60 cm. overall size.

(10) The chart is to be entitled "Armed Forces Visual Acuity Test."

The following recommendations were made by the Subcommittee for changes in the sample near chart:

(1) Since the acuity portion of the near chart is to be a photographic reduction of the far chart, all the corrections listed above will apply to the near chart.

(2) The numerical line designations are to be transposed with the near acuity designations in the case of the letter chart and with the visual efficiency designations in the case of the illiterate letter chart.

(3) The reading material presented in Figure 4 will be satisfactory when printed from a new plate. (The near chart was printed from an old plate just in order to mock up a reading card.)

Representatives of the military departments requested that a 20/400 letter chart be prepared for clinical use. The Subcommittee recommends that the chart be constructed as follows: The chart is to be the same over-all size as the present chart, but should be hinged in the middle. The letters to be used are: Z H S C. Two of these letters are to be printed on each side of the chart so that a single letter may be presented by folding the chart along the center hinge.

The Subcommittee approved the following recommendation:

In view of the fact that small differences in visual acuity of the same individual will undoubtedly appear when he is tested on the presently used Snellon chart and on the new chart, it is strongly

1 N S 20°
20/200

2 Z K C R 25'
20/100 -89%

3 O R S N K 17.5'
20/70 64%

4 V H D Z C 17.5'
20/70 64%

5 S O K N C 12.5'
20/50 76.5%

6 D H Z R V 12.5'
20/50 76.5%

FIGURE 1

1 S C R K N 12.5'
20/50 76.5%

2 V Z D H O 12.5'
20/50 76.5%

3 K N S R O C Z H 10'
20/40 83.6%

4 O V K D S C N H R Z 7.5'
20/30 91.5%

5 C N K O S V R Z H D 6.25'
20/25 95.7%

6 N V D O Z R C S K H 5'
20/20 100%

7 R V K C N Z S D O H 5'
20/20 100%

8 N S O K D H C Z V R 5'
20/20 100%

9 D V Z K R H C N S O 5'
20/20 100%

10 H K O D V N C S Z R 3.75'
20/15 104.6%

11 Z H C R V D S N K O 2.5'
20/10 109.3%

FIGURE 2

1	14/140	NS	1	20 7/8	EW
2	14/70	ZKCR	2	48 9 7/8	ЭМЭW
3	14/49	ORSNK	3	64 7/8	EWЭEM
4	14/49	VHDZC	4	64 7/8	WEЭEW
5	14/35	SOKNC	5	76 5 7/8	WMЭWE
6	14/35	DHZR V	6	76 5 7/8	ЭWEWM
7	14/35	SCRKN	7	76 5 7/8	ЭEWЭЭ
8	14/35	VZDHO	8	76 5 7/8	EWЭЭЭ
9	14/28	KNSRO CZDHV	9	83 6 7/8	ЭWEMWЭMEЭM
10	14/21	OYKDS CNHRZ	10	91 5 7/8	ЭЭЭЭЭЭЭЭЭЭ
11	14/175	NYKDS CNHRZ	11	95 7 7/8	ЭЭЭЭЭЭЭЭЭЭ
12	14/175	ORROS YRZHD	12	95 7 7/8	ЭЭЭЭЭЭЭЭЭЭ
13	14/14	YKDS CNHRZ	13	100 7/8	ЭЭЭЭЭЭЭЭЭЭ
14	14/14	YKDS CNHRZ	14	100 7/8	ЭЭЭЭЭЭЭЭЭЭ
15	14/14	YKDS CNHRZ	15	100 7/8	ЭЭЭЭЭЭЭЭЭЭ
16	14/14	YKDS CNHRZ	16	100 7/8	ЭЭЭЭЭЭЭЭЭЭ
17	14/105	YKDS CNHRZ	17	104 6 7/8	ЭЭЭЭЭЭЭЭЭЭ
18	14/105	YKDS CNHRZ	18	104 6 7/8	ЭЭЭЭЭЭЭЭЭЭ
19	14/84	YKDS CNHRZ	19	107 4 7/8	ЭЭЭЭЭЭЭЭЭЭ
20	14/7	YKDS CNHRZ	20	109 3 7/8	ЭЭЭЭЭЭЭЭЭЭ

FIGURE 3

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I walked up the street, going about, until near the market house I met a boy with bread. I had made money a while on board, and asked him where he got it. I then went to the baker's and asked for bread such as we had in Boston. I asked for a three penny loaf and was told

that they had none such. Not knowing the difference of money and the greater cheapness, I told him give me three penny worth of any sort. He gave me three great puffy rolls. I was surprised at the quantity but took it, and walked off with a roll under each arm.

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Thus I went up Market Street as far as Fourth Street, passing by the house of Mr. Read, my future wife's father. She, standing at the door, saw me and thought I made a most awkward appearance, as I certainly

did. Then I turned and went down Chestnut Street and a part of Walnut Street, and found myself again at the wharf. Being filled with one of my rolls, I gave the other two to a woman and her child.

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By this time the street had many clean and well dressed people in it, all walking the same way. I joined them and was led into the great meeting house of the Quakers

I sat down among them and after looking around a while and hearing nothing said, I fell fast asleep. This was the first house I was in, or slept in, in Philadelphia.

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Looking in the faces of people, I met a young man whose countenance I liked, and asked if he would tell me where a stranger could get lodging. "Here", said he, "is one place that entertains strangers, but it is not a reputable house. If thee wilt walk with me, I will show thee a better." He brought me then to a place in Water Street, where I engaged a room and got dinner.

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While I was eating it several sly questions were asked me, as it seemed to be suspected from my youth and appearance that I might be some runaway. After dinner, my sleepiness returned, and being shown to a bed, I lay down without undressing and slept soundly till six in the evening.

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Our city, though laid out with beautiful regularity, the streets crossing each other at right angles, had the disgrace of allowing those streets to remain long unpaved. The wheels of heavy carriages plowed them into a quagmire.

FIGURE 4



urged that the three military departments issue a directive coincident with the distribution of the new chart specifying that it alone be used.

The Chairman asked Dr. Louise Sloan to discuss her plans for the research study of visual acuity with various test objects which is being made in the Orthorater. Dr. Sloan presented a suggested procedure for the research, an abstract of which is presented below:

Suggested Procedures for Comparative

Study of Three Types of Acuity Target

Test Material

The 3 types of target consist of checkerboards, Landolt rings and block letters, on slides which are to be placed in the distance drum of the Orthorater.

The checkerboard material comprises 3 separate slides; (1) a standard Orthorater slide for the right eye, with 15 equal steps of acuity (0.1 to 1.5), (2) a similar standard slide for the left eye,* and (3) a special slide containing for each eye, 10 targets at each of 3 acuity levels (0.5, 0.7 and 1.0). These additional targets at the higher levels are added in order to provide more reliable measures at these particularly important cut-off points.

In order that comparison of the targets as to reliability, etc., may be uninfluenced by differences in the range and in the graduation of steps in acuity, the same 15 steps are provided in the ring and letter slides as are used in the standard checkerboard slides (1) and (2). The ring and letters slides have 10 characters at each level except at 0.1 where there is space for only 5. While the checkerboard is at an obvious disadvantage because of the smaller number of targets, this is a necessary condition in actual practice, because in the same available space only this smaller number of checkerboard targets can be displayed.

In order to reduce the brightness of the background to a level comparable with that accepted as standard in testing acuity with wall charts, (Manual of Instruction for Testing Acuity - Armed Forces-NRC Vision Committee) the piece of double-flashed opal glass in the far drum of the Orthorater is to be replaced with pot opal glass, of about 3/32 inches in thickness. This thickness provides a background brightness of about 30 ml. A thicker glass reducing the brightness to about 12 ml would be still better if it can be supplied by Bausch and Lomb.

Sample mimeographed record blanks for recording the responses of the subjects are enclosed.

Test Procedure and Scoring

The order of administration of the tests with the three types of target should be systematically varied for different subjects. Within each test the right eye should, for uniformity, be examined before the left eye. A. Checkerboard - On checkerboard slide 1, the subject starts with target 1 and continues until an error is made. The test is then repeated, starting as before with target 1, and continuing until an error is made. The score for each run is the last item read correctly.

*Since the non-tested eye is to be occluded, these two slides can be combined in a single slide if this type of target is finally adopted.

(While this procedure gives on the average, a lower acuity score than that given by the procedure of Sulzman, Cook and Bartlett (last target named correctly before two successive misses) it appears to give results in closer agreement with those of the 3 level checkerboard test which has ten targets at each level. (See Table 1). This finding suggests that correct responses after one failure are more likely to be a result of chance guessing of the correct answer than of true discrimination of the checkerboard). In administering slides (1) and (2) the examiner must make sure that the subject is not confused by the fact that targets 4 to 7 read from right to left, not left to right. On slide (3) of the checkerboard test, the subject is given credit for the lowest level at which the subject gives correct answers to 8 or more of the 10 targets. If he fails acuity level 0.7 for example by making more than 2 errors, all of this group should be attempted, but the smallest group (level 1.0) may be omitted.

B. Landolt Ring Test and Letter Tests. - The subject's task in the former test is to report the location of the break in each ring, in the latter to identify the letters. He is told that the opening in the ring will point either right, left, up or down. The examiner's task in each of these tests is to determine the lowest level at which the subject can give correct responses to 7 of the 10 characters. It is desirable for purposes of statistical analyses of the results, to know in addition, the lowest line on which no errors are made, and the exact number of errors on the first line which the subject fails, (i.e. makes more than 3 errors). The following procedure is, therefore, suggested. Let the subject start with the lowest line on which he thinks he can easily see the breaks, or read the letters. If no errors are made he is allowed to proceed to the next lower line. If the subject makes one or more errors on the first line he elects to read, he is asked to read successively higher lines until one is reached on which he makes no errors. The test is discontinued when 4 or more of the 10 rings on a line are read incorrectly. The test should not be stopped in the middle of a line, even though the first four characters are read incorrectly.

If the above procedure should prove impractical, because too time consuming for example, it may have to be modified. The reasons for suggesting this procedure are as follows. By having each subject select a level just above his threshold instead of starting at the top of the chart, subjects with different acuities will have more nearly equal amounts of practice in reading easier characters before reaching the critical level. Completion of the last line read, even though 4 errors have already been made, is suggested for this particular study so that comparisons can be made of the sharpness of cut off for different targets, and so that different passing criteria other than the suggested one of 7 of 10 correct may be investigated. The other requirement, i.e. establishment of the lowest level at which no errors are made, is suggested in order to provide additional data for evaluating the range of difficulty of the different test letters. It could be omitted if necessary.

Evaluation of 3 types of acuity target

I. Collect data suitable for determination of reliability of each test, and inter-correlation between acuity scores for each type of test. If two tests of acuity are found to correlate highly with one another, regression equations may provide further information as to equivalent scores on the 2 tests.

II. In obtaining the data for I, information should also be forthcoming as to the ease of giving and scoring each of the 3 tests, average time required for each, etc.

III. Relationship between (a) acuity and (b) type and amount of refractive error for each of the 3 acuity tests.

The possible effects of uncorrected spherical errors and of cylindrical errors at different axes have been discussed from the point of view of blurring of the retinal image by Fry (The significance of visual acuity measurements without glasses, Glenn A. Fry, Amer. J. Optom. and Arch. Amer. Acad. Optom., vol 25, 1948, pp. 199-210). Direct data bearing on this problem can be obtained by testing two groups (a) subjects with various degrees of simple myopia (b) subjects with various degrees of myopic astigmatism. Cases of simple hyperopia and simple hyperopic astigmatism should be excluded unless accommodation is paralyzed during the acuity tests. This is because the amount of accommodation exerted by the subject will influence the amount of "effective refractive error" in an unpredictable manner.

These data should be analyzed by suitable statistical procedures to determine the general relationship between acuity and diopters of refractive error for the 3 types of acuity target and for 3 types of refractive error, namely (a) spherical errors, (b) astigmatic errors at oblique axes and (c) astigmatic errors at vertical and horizontal axes. Fry's analysis suggests that acuities measured with targets of the letter type will correlate more closely with acuity measured with checkerboards when the refractive errors are of types a and b than when of type c. If this proves to be the case, it suggests that the "letter factor" found in PRS Report No. 742 AGO, is perhaps related to the different effect of astigmatic errors at 90° and 180° on letters and on checkerboards.

Additional Comments:

The above suggestions are presented merely as a starting point. It is hoped that the investigators who are asked to cooperate will use the test material in any way they believe suitable, in order to evaluate the relative merits of the 3 types of acuity target.

I realize that 3 variables are insufficient for a factor analysis study. Such an investigation would probably require additional tests selected so as to emphasize the "brightness discrimination" factor, the "machine" factor, the "absence of machine" factor, the "letter" factor and the "retinal resolution" factor, and at least two "refractive error" factors. In a population in which refractive error is not eliminated experimentally (by having the subjects wear the necessary correcting lenses) refractive errors are in my opinion the most obvious and important determiners of acuity. Such factors were not considered directly in the AGO study except in the case of the so-called "lens accommodation" factor. Except for a few individuals with presbyopia or high degrees of hyperopia, all subjects in that study may be assumed to have had powers of accommodation more than adequate for the near distance. Myopic subjects on the other hand, have significantly different effective refractive errors at near and at far. The acuity data for the latter group therefore, reduce the correlation between acuity measures at the two distances. This "near" factor is probably not an "accommodation" factor, but one of the complex of factors related to effective refractive error.

~~RESTRICTED~~Table I

Relationship between scores on three-step and on 15 step checkerboard test by two scoring methods.

Score A. Three-step test. Lowest line on which 8 of 10 characters are read correctly.

Score B. 15 - step test. Last item before first miss.

Score C. 15 - step test. Last item before 2 successive misses (If item 15 is failed, failure on non-existent item 16 is assumed).

Data are given only for subjects having different B and C scores.

SCORES

<u>Case</u>	<u>A</u>	<u>B</u>	<u>C</u>
1	7	9	15
2	7	8	10
3	7	8	11
4	7	9	11
5	7	6	8
6	7	4	7
7	7	10	12
8	7	5	7
9	7	8	13
10	7	6	8
11	7	8	11
12	7	7	11
	Av. 7	Av. 7.3	Av. 10.3

~~RESTRICTED~~

MEETING OF THE SUB-COMMITTEE ON VISUAL DISPLAYS

13 and 14 November 1949

The following persons were present at the meeting on Sunday evening, 13 November 1949:

Dr. Walter F. Grether	- Chairman
Dr. Jack W. Gebhard	- Member
Dr. Alphonse Chapanis	- Visitor
Major Marvin E. Kay	- Visitor
Mr. Michael Goldberg	- Visitor
Mr. John H. Taylor	- Visitor

The following persons were present at the meeting on Monday morning, 14 November 1949:

Dr. Walter F. Grether	- Chairman
Dr. Jack W. Gebhard	- Member
Dr. John E. Kennedy	- Member
Dr. Leonard C. Mead	- Member
Dr. James J. Gibson	- Visitor
Dr. Arnold M. Small	- Visitor
Surg. Com. Eric James	- Visitor
Capt. T. L. Willmon	- Visitor
Mr. William R. Sidle	- Visitor
Mr. John H. Taylor	- Visitor
Mr. Fred R. Brown	- Visitor

Meeting of Sunday evening, 13 November 1949. Since only the Chairman, one member, and four visitors were present at this meeting, only general discussion of matters on the agenda was possible. The entire agenda was again discussed the following day, when two additional members of the Subcommittee and a larger group of visitors were present. All decisions for action were deferred until Monday morning.

Meeting of Monday morning, 14 November 1949. Standards to be Employed in Research on Visual Displays. The Chairman reviewed the previous actions of the Subcommittee which held its first and only previous meeting at Ann Arbor, Michigan, on 4 and 5 April 1947. At this earlier meeting, agreement had been reached concerning standards to be employed in research on Visual Displays. These were subsequently published in a report issued by the Vision Committee under the date of 1 October 1947. This report had been distributed among the research workers in this field, with suggestions that it be followed wherever possible as a guide.

At the present meeting, the Sub-Committee reconsidered the previous standards as published in the 1 October 1947 report. It was the consensus of those present that the report had been quite useful and that the prescribed standards had been well chosen. In going through the report, a number of changes in wording were agreed upon. It was also decided to add to the report a table of time values for dark adaptation following exposure to various intensities of adapting light. A revised report will be issued incorporating the agreed upon changes.

Some discussion was devoted to the future use and distribution of this report. Rather than publish the report in a psychological journal, as suggested by the

chairman, it was agreed that the report should again be issued by the Vision Committee, and given somewhat wider distribution than previously. Also, the report will be sent to the Editor of the Psychological Abstracts, with the suggestion that it be abstracted in that journal.

Preparation of Bibliography. As a possible additional activity for the Sub-Committee, the preparation of a bibliography covering the field of visual displays was discussed. A serious problem in such an effort would be the decision of where to draw the line between visual displays research and general research in vision. It seems also that a number of existing reports provided quite adequate bibliographies of visual display reports even though the references are not isolated and organized as they could be for greatest convenience. Instead of engaging in such a bibliographical project, it was decided that references to the most useful surveys of literature in this field would be added to the revised standards report. Thus there will be a bibliography of bibliographies added to that report.

Recommendations for Optimal Design of Visual Displays. Considerable attention was devoted to a discussion of whether or not the Visual Displays Sub-Committee should attempt to prepare specifications or recommendations for the optimal design of visual displays. This would appear to be a very appropriate effort for this Sub-Committee. Such recommendations, properly prepared, would be quite useful to engineers and others actually engaged in the design of displays. Quite recently a number of reports have been published which to some extent fill the need for such recommendations regarding visual displays. The more directly applicable of these are a book by Chapanis et. al., entitled "Applied Experimental Psychology"; USAF Technical Report 5829, "Psychological Aspects of Equipment Design," by Fitts; and USAF Technical Report 5765, entitled "Studies Pertaining to the Design of Visual Displays for Aircraft Instruments, Computers, Maps, Charts, Tables and Graphs: A Review of the Literature," by Kappauf. Soon to be published is a "Handbook of Human Engineering Data" being prepared by Tufts College for the U. S. Navy Special Devices Center. Because of these other reports covering work in the visual displays area, it was decided that no project would be launched at the present time for the preparation of recommendations or specifications for visual displays. This question will be brought up again at future meetings for further consideration.

Important Research Areas. In the discussion of the Sub-Committee, it became clear that there are major gaps in our knowledge concerning visual displays, to which greater attention should be devoted. The areas of research singled out for specific mention are as follows:

1. Comprehension or Interpretation of Visual Displays. The most severe problems in the design of visual displays are in making them easy to understand, with the minimum possibility of gross errors, rather than the problem of making them easy to see with all information adequately above threshold.
2. Design of Numerals and Letters. In spite of some recent efforts in the design of numerals and letters with regard to style, proportions and stroke width, considerable further work is necessary before we can confidently specify the optimum numerals and letters for the most prevalent viewing conditions.
3. Display of Information with Three or More Coordinates. Many problems in air traffic control and several military situations require effective methods of displaying multiple-coordinate information. Display of two-coordinate information is relatively easy, but the effective representation of additional variables has not been achieved.

4. Multiple Instrument Displays. The problem of combining instruments for saving space and clarifying the interrelations among their indications deserves greater attention.

5. Illumination of Instruments. It is believed that greater attention should be paid in the design stage of instruments to the manner in which they will be illuminated.

6. Design of Maps. There appears to be little, if any, effort devoted to the design of maps from the standpoint of human comprehension and legibility.

Future Meetings. In concluding, it was agreed that the Sub-Committee would meet again at the next meeting of the Vision Committee. It was decided, in addition, to schedule a series of research papers in the area of visual displays.

MEETING OF THE SUBCOMMITTEE ON VISIBILITY AND ATMOSPHERIC OPTICS

November 13, 1949

The initial meeting of the Subcommittee on Visibility and Atmospheric Optics was scheduled for 8:00 p.m., November 13. The Chairman of the Subcommittee and a number of the members did not reach Pensacola in time for the scheduled meeting of the Subcommittee, due to transportation delay resulting from bad flying conditions. As a consequence, the Sunday evening meeting was devoted to an impromptu discussion of the implications of visibility research results upon problems of meteorology.

Mr. Middleton opened the discussion with a statement of the interests of the Subcommittee on Atmospheric Optics of the International Meteorological Organization, of which he is President. This organization is interested, among other matters, in standardizing a value for Epsilon, the contrast threshold of the eye for an indefinitely large, dark object. The traditional value for Epsilon of 0.02 has received much favor in the older literature. However on the one hand, recent atmospheric transmission measurements such as those made by Mr. C. A. Douglas, have indicated in-directly that the value for Epsilon should be of the order of 0.055 rather than the more classical 0.02. On the other hand, recent contrast threshold measurements of the human eye, such as those by Dr. H. R. Blackwell, have indicated that the threshold contrast in the laboratory is more like 0.0028 than 0.02. Mr. Middleton asked whether any of those present could cast any light upon the problem of the apparent large discrepancy between the value of Epsilon inferred from atmospheric transmission measurements and the value measured in the laboratory.

Dr. Blackwell reported some recent results obtained at the University of Michigan which he believed had bearing on the problem. In a recent experiment, 40 inexperienced subjects were tested for the detection of a point source target seen against a high luminance background. The experiment was intended to indicate the degree of subjective awareness of discrimination corresponding to various levels of successful discrimination in the so-called forced choice psychophysical situation. The subjects were brought into the laboratory without previous threshold determination experience. They were asked merely to respond as to whether or not they saw the point source when it was presented. The point source target was presented during a 2 second time interval whose beginning was indicated by a signal buzzer. The observers knew where to expect the target since it always appeared in the center of a configuration of orientation points. Thus, the observers knew exactly where and when the stimulus was to appear.

After several nights of "naive" discrimination report, the subjects were acquainted with the forced-choice psychophysical technique. All conditions were exactly the same except that now four 2 second time intervals were used, each clearly set off by a warning signal buzzer. In one of the four time intervals, the point source was presented, and in three, nothing was presented. The observers were forced to guess which of the four intervals contained the target presentation, and they were not allowed to refrain from guessing on any given set of four such presentations.

At the conclusion of a number of experimental sessions with the forced-choice method, the subjects were again asked to make the yes-no response which had been required of them during their initial sessions in the experimental set up. There was no evidence of a significant shift in the number of yes responses from the first to the final session of this kind. We are thus able to compare directly the

percentages of correct forced-choice response with the percentages of yes responses. On the average, for the 40 subjects, 95% correct forced-choice responses occurred at a stimulus intensity 2.2 times the intensity at the 50% forced-choice response level, classically defined as the intensity threshold. The observers obtained 98% correct response at approximately 2.6 times the threshold intensity and 99% response at 3.2 times the threshold intensity. The 50% point for "naive" yes response occurs at a value 1.74 times the threshold obtained by the forced choice technique. 95% yes response occurs at 4.0 times the forced-choice threshold; 98% occurs at 5.0 times the forced-choice threshold, and 99% yes response occurs at 5.5 times the forced-choice threshold intensity.

These data reveal the general order of magnitude of the relation between correctness of forced-choice response and the proportion of yes responses obtained from inexperienced laboratory subjects. A high level of subjective confidence in discrimination, as for example, 98% of yes responses, occurred at a stimulus intensity 5.0 times the threshold intensity in the laboratory psychophysical method.

The implications of the study for the problem of determination of Epsilon were discussed. It was, of course, obvious that one could not necessarily assume that the same relationship would occur with indefinitely large targets as had been obtained in the present study utilizing point source targets. However, the results may indicate the order of magnitude of the effect to be expected with large targets. The consensus of opinion in the group was that 98% of yes responses was probably not an unreasonable level of confidence to assume for meteorological observers when observing visibility markers. Thus, it might be appropriate to multiply laboratory threshold contrast by a factor of 5.0 for use in meteorological applications. If one thus "corrects" the Tiffany long-duration threshold for an indefinitely large object at high luminance, one obtains a value of 0.014. If one multiplies the threshold contrast obtained with the 6 second search procedure by the same factor, one obtains a value of 0.028. It was the consensus of the group that the search data were more appropriate for application to the meteorological situation than the long-duration data. We might thus expect a value of Epsilon of the order of 0.028 which is greater than the classical value of 0.02, but still less than the value inferred from atmospheric transmission measurements.

Dr. Blackwell suggested the possibility that an additional factor is involved which is not normally taken account of in laboratory determinations of threshold. This factor concerns the importance of informing the subject in which portion of time the stimuli may be expected to appear. In a normal field situation, the meteorological observer cannot expect a visibility marker to appear for two-seconds following a warning buzzing, and then to disappear. It seemed possible that the prescribed temporal sequence which is usually present in the laboratory determinations of threshold would serve to increase the probability that a subject could make a correct discrimination because he would be able to reject hallucinatory impressions of stimulation since the latter would fail to follow the prescribed course of temporal events.

Dr. Blackwell described some preliminary results obtained in attempting to evaluate the significance of this factor. The determinations were made utilizing the detection of a point source target against a high luminance background, as before. Inexperienced subjects were first required to respond yes when they were aware of the presentation of a stimulus following a warning buzzer in the same manner used in the experiment described above. The procedure was then altered so that a stimulus was presented only once in a 30-second period. The subjects were informed of the change and were told that they would not be warned as to exactly

when it would occur during the 30-second interval. They were instructed to expect stimuli to occur at various portions of the 30-second interval on successive presentations. A comparison of the number of yes responses under the two situations revealed that the threshold for the yes response was 1.72 times as great when the 30-second interval was used as when the demarcated 2-second interval was used. This result would indicate that either the subjects became inattentive during the 30-second presentation period or else that the crudeness of determinancy of the temporal sequence of events did not permit them to discriminate real from hallucinatory stimuli. Dr. Blackwell favored the second interpretation. He reported his own experiences in the experiment in which near threshold he often "saw" point sources when stimuli were actually not being presented. It is possible to learn to discriminate the real from the hallucinatory stimuli in the normal laboratory sequence because of the peculiar temporal characteristics of the real stimuli as compared with the hallucinatory stimuli.

There was some discussion of the degree to which these data could be applied to the problem of the value for Epsilon. Dr. Blackwell suggested the possibility that this effect would be much less apparent for large stimuli. There are, at present, no data upon which to base such a conclusion; it must be regarded merely as a hunch. If this effect is a real one, and if it is relevant to large stimuli when observed by meteorological personnel, then one could increase the appropriate value of Epsilon by the additional factor of 1.72. Utilizing the Tiffany threshold data corrected by the factor of 5.0 described above, values for Epsilon come out to be 0.024 for the indefinitely large search data, and 0.048 for the 6-second search data.

Some members of the group seemed to feel that the complexity of the visual threshold problem suggested the desirability of adopting a value of Epsilon based upon inferred data from transmission measurements such as those obtained by Mr. Douglas. Dr. Blackwell agreed with this point of view since it was clear that the visual problem was complex and the results obtained to date did not permit a satisfactory solution to the problem of Epsilon determination. He expressed his belief, however, that the experimental data reported might help to remove the apparent mystery of the large difference between laboratory threshold data previously reported and the values of Epsilon obtained by inference from physical measurements.

Mr. Middleton expressed his hope that someone could determine thresholds for horizon-like stimuli; that is, stimulus boundaries of unlimited extent. Dr. Blackwell expressed his concurrence with this suggestion. He stated his belief that the threshold for an extended boundary such as a horizon line was not very different from the threshold for an indefinitely large object located in a uniformly bright field.

The group then discussed the possibility that meteorology observers could utilize convenient, small visibility markings in making visibility observations rather than being restricted to the use of indefinitely large dark objects which are, of course, practically never in existence at meteorological stations. Dr. Blackwell exhibited a conversion table based upon the Tiffany visual threshold data which would permit a meteorological observer to make this observations with any convenient size and contrast target and then convert the reading into the reading he would have gotten had he been in possession of an indefinitely large dark visibility marking. The principle is simple. The Tiffany threshold data demonstrate the relation between threshold contrast and stimulus area. Once the value of Epsilon is standardized, the Tiffany data may be used to establish conversion factors by simply computing the ratio of the logarithm of Epsilon relative to the logarithm of the visual threshold contrast for the size marking under consideration, this latter value expressed in terms of the visual threshold contrast for an indefinitely large object. Such a conversion

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table would apparently permit meteorological observers to use convenient visibility markings and then make the necessary conversions to standard visibility markings. The absolute values of threshold contrast of the Tiffany data need not concern us in making the conversion table. The only question is whether the relation between laboratory threshold and "field threshold" is the same at different sizes or whether the difference is a variable one. Dr. Blackwell expressed his interest in tracking down this problem. Mr. Middleton expressed his hope that it would be possible at some future time for such determinations to be made.

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STUDIES OF ATMOSPHERIC ATTENUATION OF BRIGHTNESSCONTRAST AT THE UNIVERSITY OF TEXAS FROMMARCH 1949 THROUGH NOVEMBER 1949Howard S. Coleman
University of TexasABSTRACT

It is the purpose of this report to describe the progress made in the study of the attenuation of brightness contrast by the atmosphere at The University of Texas from 4 March 1949 to 12 November 1949. During this period, these studies consisted of three parts. The first of these involved the comparison of photographic and visual measurements of the attenuation of brightness contrast by the atmosphere with measurements made under the same conditions using a photoelectric telephotometer described at the 4 and 5 March 1949 Vision Committee Meeting. The second part consisted of a study of the limitations imposed by optical haze on the measurement of the attenuation of brightness contrast by the atmosphere. The third part consisted of a study of the influence of the meteorological range upon wavelength. It is the purpose of this report to describe the results of these studies.

THE COMPARISON OF PHOTOGRAPHIC AND VISUAL DATA WITHPHOTOELECTRIC ATMOSPHERIC ATTENUATION DATA

Two studies were made during the period covered by this report which were designed primarily to explain the great dispersion of data reported by early investigators in the field of atmospheric attenuation. For the most part the data reported were intended to support theories developed which were based on assumptions which rarely if ever held in nature and accordingly were obtained under only those conditions believed to closely approximate the assumptions made in the theoretical developments. Even with such restrictions, these early data showed so much dispersion that real doubt was cast upon the value of the theoretical developments. The University of Texas program in the field of Atmospheric Optics has shown that the attenuation of brightness contrast of objects by the atmosphere is a simple exponential function of range and furthermore this function holds for a wide variety of conditions of the weather. Inasmuch as this result appears to be in conflict with the early data mentioned, every effort has been made to attempt to resolve these differences. In this regard, considerations as to a possible faulty technique in the photoelectric measuring procedures, etc., were considered. When no such considerations led to any reasonable explanation of the failure of the early investigators to demonstrate satisfactorily the existence of the exponential law, two auxiliary experiments were conducted using other photosensitive receptors. These consisted of a comparison of atmospheric attenuation data obtained photographically with that obtained photoelectrically and a comparison of atmospheric attenuation data obtained visually with that obtained photoelectrically. The details of these comparisons are described in the following sections.

The Comparison of Photographic and Photoelectric Data

A comparison of atmospheric attenuation data using photographic and photoelectric methods was made using four interference filters which limited the attenuation measurements to four practically monochromatic regions of visible spectrum. The apparatus used included two telephotometers. One of these is a photoelectric device

and the other is photographic. These are shown schematically in drawing D-5676 and drawing D-6247. The arrangement of the grey scale used in connection with the photographic photometry is shown in drawing D-6438. This grey scale together with the visibility targets used in the study are shown in photograph P-5230. The linearity of the photoelectric response of the photoelectric telephotometer is shown in drawing D-6009. The spectral response of the photoelectric tube is shown in drawing D-6010. The spectral transmittance data for the filters used are shown in drawings D-5970, D-5971, D-5972, and D-5973. In the photographic process, Super XX film was used. This was processed in Microdol developer in accordance with the manufacturer's instructions.

The procedure used consisted of simply making a comparison of attenuation of brightness contrast measurements using the two telephotometers for each of the filters described. Conventional H and D curves for the grey scale and the data obtained for black targets for each of the above mentioned filters were obtained in the case of the photographic photometry. These curves together with the direct measurements using the photoelectric telephotometer, were used to determine the attenuation contrast of each of the targets located at various distances from the telephotometers.

Typical data showing the comparison of the photographic and photoelectric data are shown in drawings D-6612, D-6613, D-6578, and D-6615. These drawings show the rectified plots of the logarithm of the apparent contrast of the target as a function of range for each of the telephotometers and each of the filters.

It is evident from the data presented that the photoelectric and photographic methods of measuring the attenuation of brightness contrast by the atmosphere lead to the same results. For this reason it should be possible to compare photoelectric and photographic data without any question as to which of the two may be expected to yield the better results.

A Comparison of Visual and Photoelectric Data

Inasmuch as it is frequently desirable to make atmospheric attenuation measurements using visual photometers, and since some of the data reported in the literature were obtained using such photometers, a comparison was made between the atmospheric attenuation determined by visual photometry with that determined by means of the photoelectric device mentioned. The apparatus consisted of two telephotometers. One utilized the human eye as a photosensitive receptor and the other used a photoelectric tube. These are shown schematically in drawings D-5676 and D-6611. The procedure used consisted in making a comparison of brightness measurements of the visibility targets described previously using the two telephotometers. The photoelectric measurements were made first and immediately thereafter (with a period of 1 minute) visual brightness measurements were made of each of the visibility targets and the sky background against which they were viewed. Samples of the data obtained in these measurements are shown in drawings D-6641, D-6642, D-6643, and D-6644.

It is evident from the above mentioned data, that the visual and photoelectric measurements of the attenuation of brightness contrast by the atmosphere are in close agreement. For this reason, there is little doubt as to the fact visual photometry should yield the same result as photoelectric methods. This tends to indicate that early experiments conducted in measuring the attenuation of brightness contrast using visual methods must not have been properly designed, otherwise close adherence of the attenuation data to the simple exponential function would have been found to hold.

LIMITATIONS IMPOSED BY OPTICAL HAZE ON THE MEASUREMENT OF
THE ATTENUATION OF BRIGHTNESS CONTRAST

It is well known that the measurement of the attenuation of brightness contrast by the atmosphere is beset by many difficulties. Fortunately many of these have been eliminated. However there is one factor related to these difficulties about which almost no objective studies have been made. This factor is referred to as "Optical haze" and is distinct from the result of molecular and nuclei types of scattering which are responsible for most atmospheric attenuation of brightness contrast. Optical haze is a result of small scale convection currents crossing the line of observation in the form of small air masses of different optical density. These differences in optical density cause minute deviations of light passing from an object toward an observer so that momentarily the light of the surround is directed along the line of sight and the light from the object is directed elsewhere. This phenomenon is commonly observed near relatively hot surfaces. Optical haze imposes severe limitations on the effectiveness of such optical devices as range finders and is particularly damaging to visibility along the surface of water.

A little consideration of the nature of optical haze will show that its magnitude is at least related to the manner in which it is being observed. For example, the inherent brightness of an object under examination, the distribution of inherent brightnesses of the region surrounding the object, and the relation of the size of the object to its immediate surround, are important factors. It is the purpose of this section of this report to describe the relation of optical haze to the problem of measuring the attenuation of brightness contrast by the atmosphere.

The limitations imposed by optical haze on the precision of the measurements of atmospheric attenuation data were explored using apparatus consisting of a photoelectric telephotometer, seven black and seven white visibility targets, the details of which have been described in previous reports to the Vision Committee. For purposes of describing the material presented here, the targets can be regarded as plane white rectangular objects having a black circular disc on them subtending an angle of 1.86 minutes with respect to the point of observation. The telephotometer used was adjusted such that the entrance pupil to the photoelectric tube used was but slightly smaller than the image formed by the black target. The optical haze could then be determined by measuring the light deviated from the surround (the white portions of the target) along the line of sight, thereby yielding an integrated effect of the image of the black portion of the target of higher luminosity than would have been obtained from the black target if the luminance of its surround were zero. This effect is illustrated schematically in drawing D-6645.

The procedure consisted simply of measuring the change in meteorological range as a function of time as the optical haze changed during the day. This was done by making one set of atmospheric attenuation measurements after another during the day and noting the change in the meteorological range. The measurements were made using a filter in the photoelectric telephotometer that renders its spectral response similar to that of the human eye. The change in meteorological range thus obtained can be interpreted as the change in "visible" range of objects that can be attributed to atmospheric optical haze.

The data obtained in this study are presented in drawings D-6646, D-6647, and D-6648. Drawing D-6646 shows the comparison of the slopes of the atmospheric attenuation data as a function of time. Drawing D-6647 shows the relative rates of

change of the meteorological range as would be determined from either black targets or white targets with respect to time. Drawing D-6648 shows the change in contrast of the black targets with respect to the white targets during the period in which the optical haze is approaching its minimum value. It is evident from the data shown that the optical haze in the atmosphere is an important factor in limiting the visibility of objects as well as limiting the precision to which the attenuation of brightness contrast measurements can be made. In this regard, it is evident that there are two periods during the day, one in the morning and the other in the late afternoon, during which optical haze is at a minimum. These two minima are associated with the reversal of the rise and fall of the small air masses that rise and fall in accordance with changes of the temperature of the Earth's surface during the day. One of these minima occurs shortly after Sunrise and the other shortly before Sunset.

It is evident that optical haze is a complex quantity, the intensity of which depends to a large extent upon the conditions of observation, particularly with respect to variations in the luminosity of the region immediately surrounding the object under examination. The ill-effects caused by optical haze in the atmosphere depend upon the observing mechanisms involved. For example, in the case of experiments described in this report, the more nearly the image of the object under consideration approaches the size of the entrance pupil to the photosensitive receptor used, the more obscuration of "vision" that would occur. In addition the relative size of the object with respect to the surround in which it is located is a major factor. For example, an object of very small subtense in a bright surround would suffer more obscuration with respect to attenuation of brightness contrast caused by optical haze than an object would having a relatively large subtense with respect to its surround. This suggests the possibility of developing an "optical haze meter" having a black target in the center of a white surround of fairly large subtense with respect to the black target.

Such considerations as are mentioned above, clearly indicate that the importance of optical haze can be evaluated only in terms of a specific set of observation conditions. For this reason, any attempt of establishing a device for measuring optical haze (an "Optical haze meter") would require that it be designed in accordance with the uses to which the information obtained by it are to be put. Fortunately the conditions of the uses to which optical haze data may be used are generally describable in terms of the photosensitive receptors involved and the observing mechanisms. Hence from a practical point of view, the allowances needed can be made to take into account any ill-effects that might arise from optical haze so far as interference with visibility measurements is concerned.

THE DEPENDENCE OF THE METEOROLOGICAL RANGE ON WAVELENGTH

During the period covered by this report, a study was started of the possible dependence of meteorological range upon wavelength. Although there is every reason, from the theoretical point of view, to expect that the meteorological range should depend upon the wavelength of the light used to measure it, the data reported by early investigators in this field are in conflict. Because the Office of Naval Research's visibility field installation at The University of Texas is particularly well-suited to study such phenomena, an investigation of the dependence of meteorological range upon wavelength was started in October, 1949. This study involves the measuring of the meteorological range using several different types of filters in the photoelectric telephotometer mentioned above. Several sets of filters were used after it was discovered that the interference filters incorporated into the photoelectric telephotometer did not isolate regions of the spectrum as well as the

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more conventional type. In this regard, interference filters are highly satisfactory where discrete spectra are involved but have a "noise level" which is generally objectionable unless they are used in series with filters which suppress the "noise level" to a value that is practically at the threshold of the photosensitive receptor used with them. Since the various sets of filters available might have shown varied results, as none were even "fairly" monochromatic, it was felt desirable to not depend on any one type of filter. The first set of filters consisted of seven Wratten units intended for use in making lens bench measurements. The second set of filters consisted of a mixture of combinations of interference filters and "photographic filters." The spectral transmittances of these two sets of filters are shown on drawings D-6798 to D-6804 inclusive and on drawings D-6829 to D-6834 inclusive. Typical atmospheric attenuation data obtained by using the two sets of filters are shown on drawings D-6806, D-6808, D-6827, and D-6828. The variation in meteorological range obtained for these sets of atmospheric attenuation data are shown on drawings D-6805, D-6807, D-6835, and D-6836.

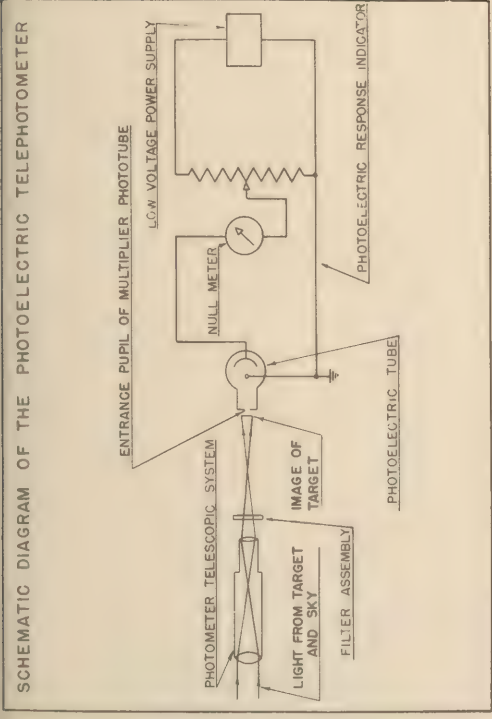
It is evident from the data shown that the meteorological range, is practically a linear function of wavelength. This is a less complex result than might have been expected. However, because of the possible relation of this function to the magnitude of optical haze present during the measurements, it is felt that this matter should be considered further (particularly from a theoretical point of view). In the event that the linear dependence of meteorological range upon wavelength can be substantiated, allowances could be made in visibility meter scales and nomographic charts for the relative visibilities of signal lights of different colors thereby greatly enhancing the usefulness of such meters and charts.

GENERAL COMMENTS CONCERNING THE ATMOSPHERIC OPTICS

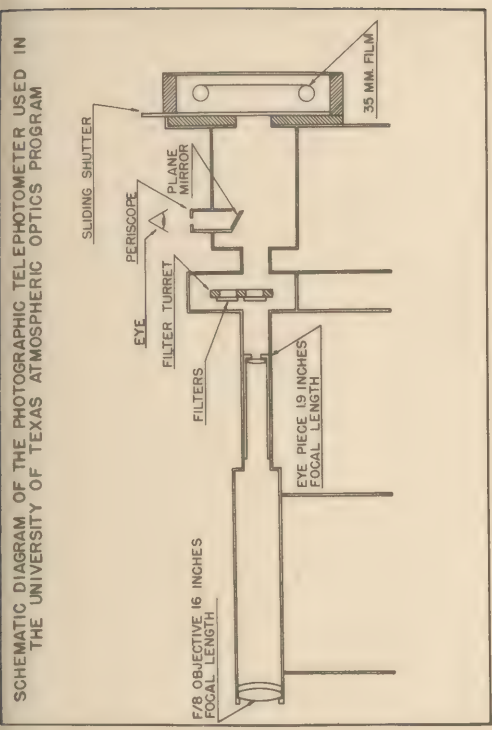
PROGRAM AT THE UNIVERSITY OF TEXAS

Because of the past endorsement of the atmospheric optics programs at The University of Texas by the Vision Committee, it is felt that the following comments may be of interest to Vision Committee members.

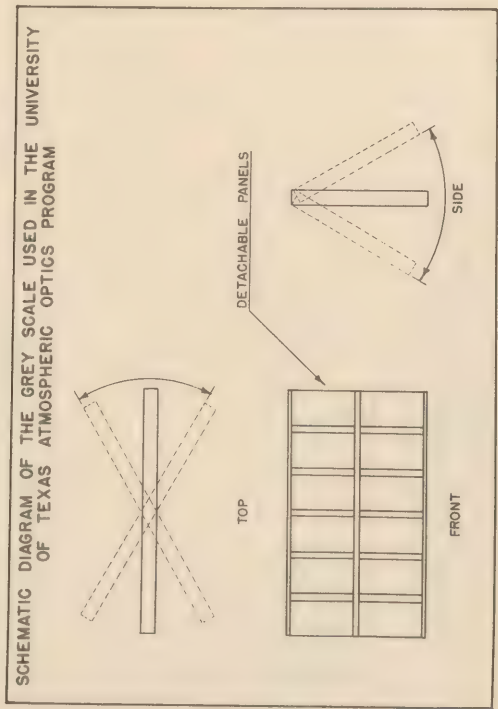
1. The atmospheric optics program is scheduled to be terminated 31 December 1949 because of the lack of financial support.
2. The University of Texas has proposed that its atmospheric optics program be continued through 30 June 1950 to permit the completion of the development of two visibility meters under consideration and the calibration (and validation) of these meters using the visibility field installation. There has been some evidence of possible support for such a limited program using Office of Naval Research funds.
3. There are two programs which the Vision Committee members have voted as needed, which have not been undertaken at The University of Texas because of lack of funds to do so. The first of these is the experimental testing of Allard's law. The second is an investigation of the dependence of meteorological range on nuclei type and concentration.
4. In the event that the atmospheric optics program is terminated, visibility targets, are to be abandoned to the property owners on whose property the components of the installation are located.



D-5676



D-6247



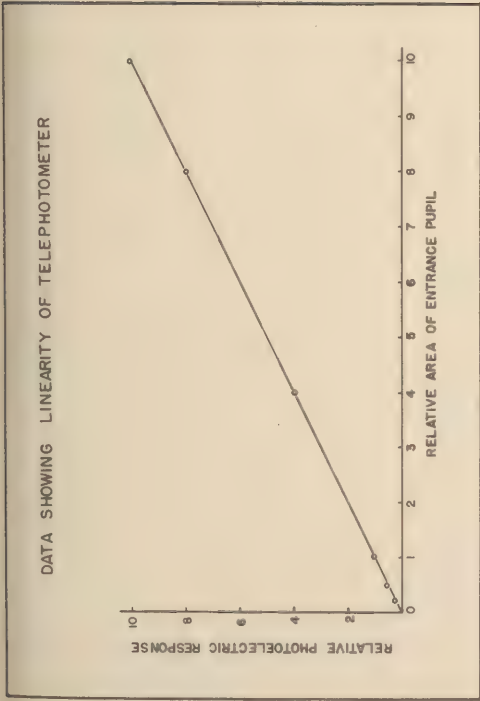
D-6438

TELEPHOTOGRAPH OF THE UNIVERSITY OF TEXAS VISIBILITY TARGETS
SHOWING THE GREY SCALE USED ON A DAY WHEN THE METEOROLOGICAL
RANGE WAS 10000 YARDS
5:15 PM 27 JUNE 1949

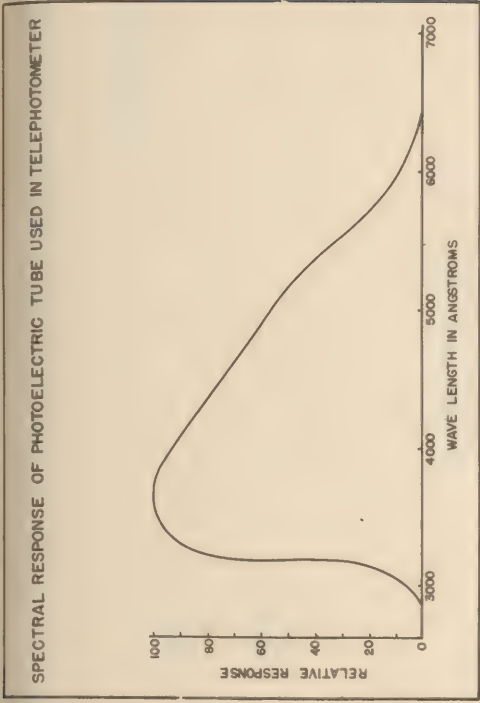


FIGURE 4

P-5230



D-6009



D-6010

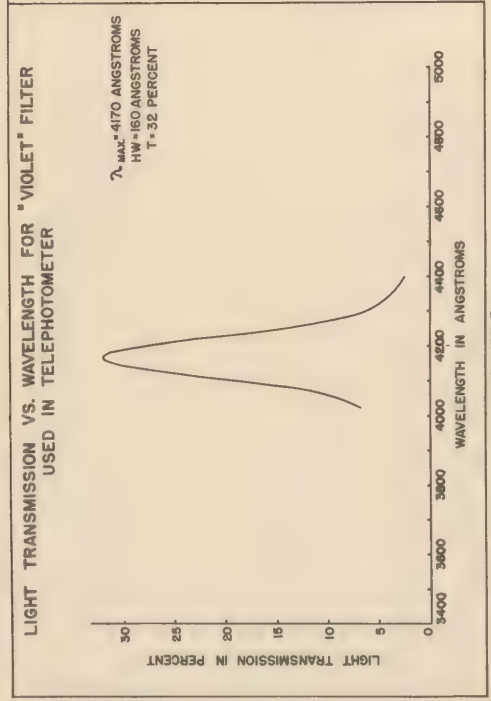


FIGURE 7

D-5970

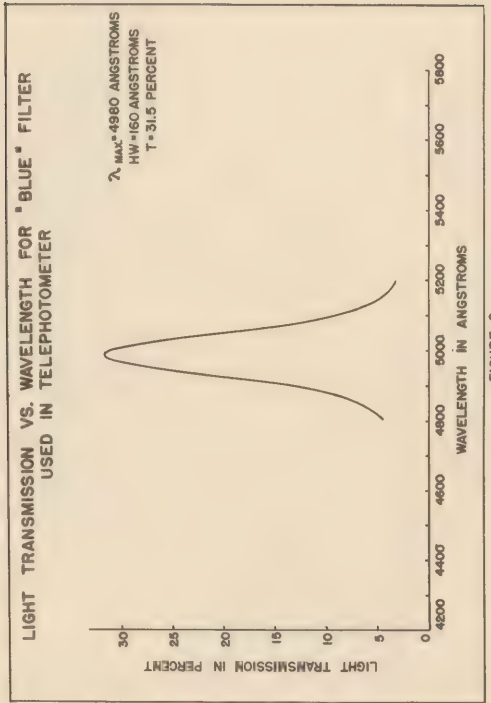


FIGURE 8

D-5971

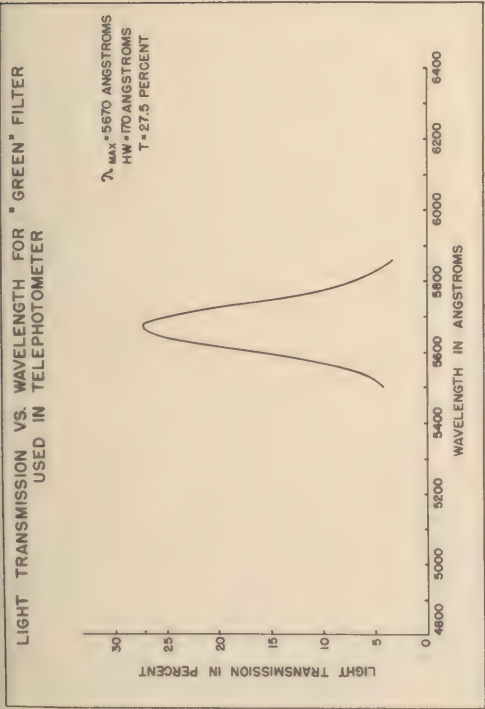


FIGURE 9

D-5972

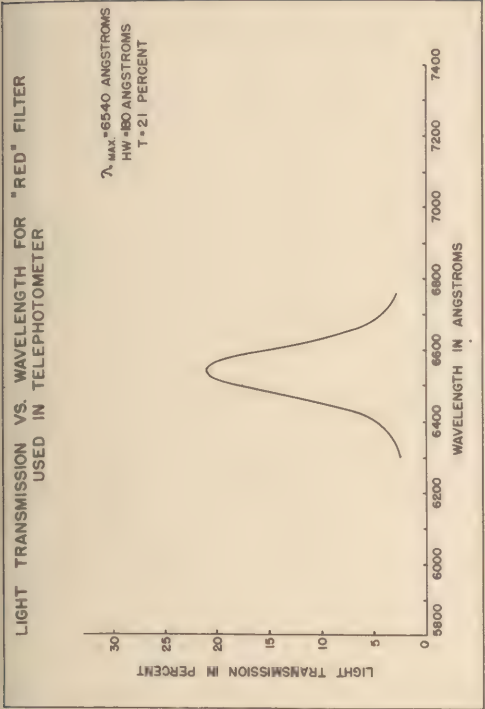
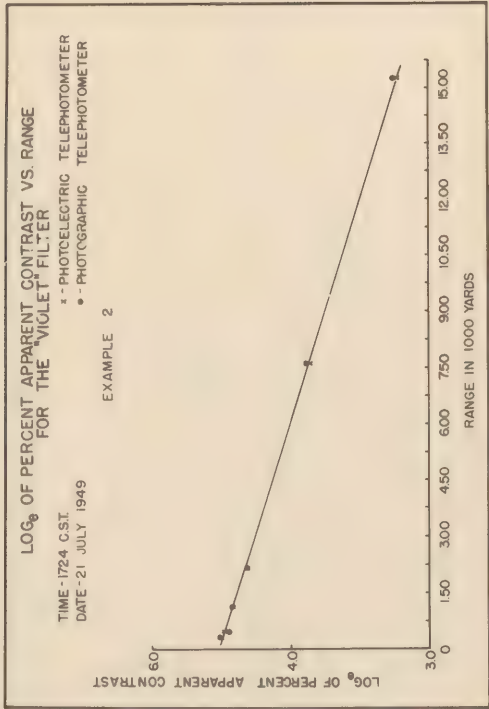
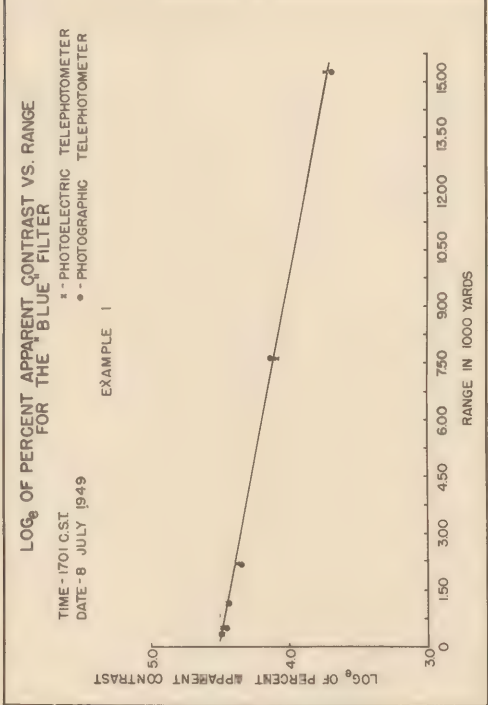


FIGURE 10

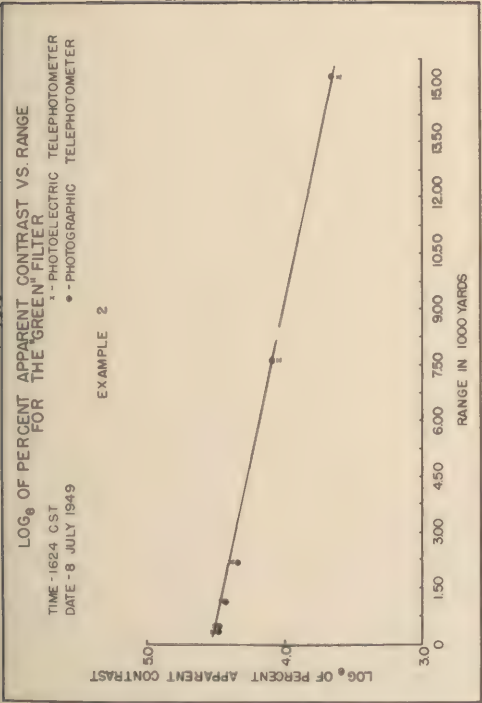
D-5973



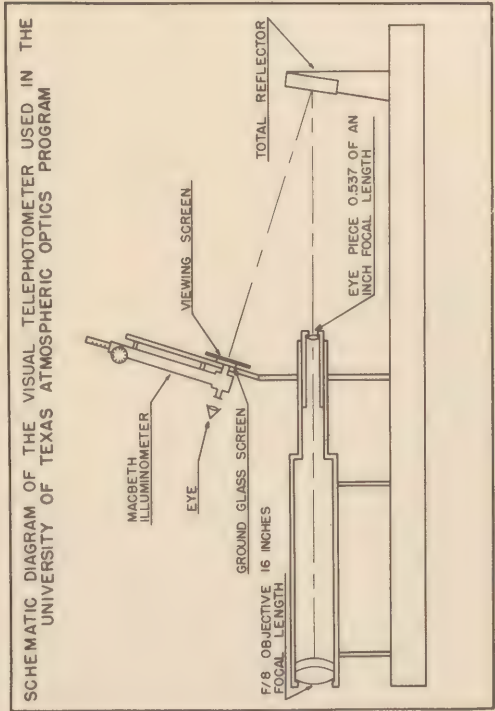
D-6612



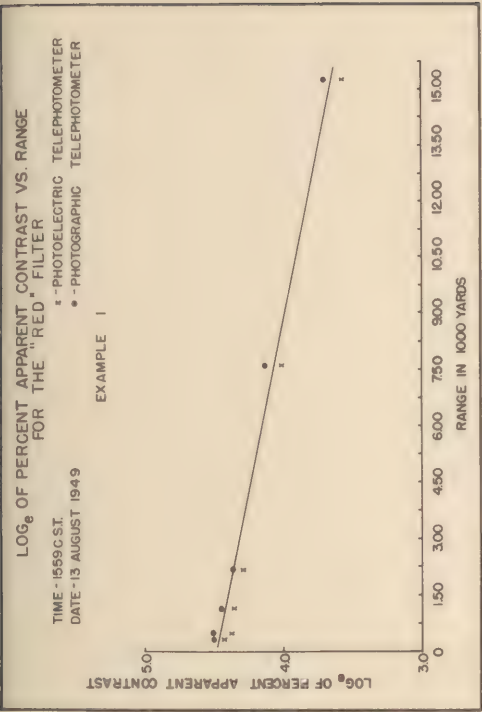
D-6613



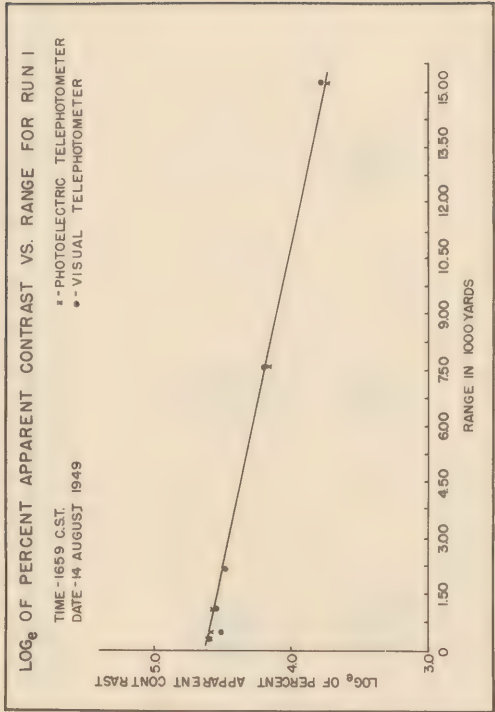
D-6578



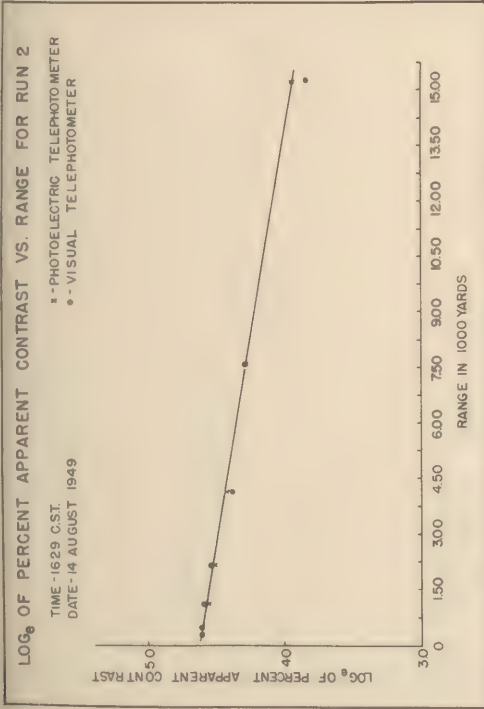
D-6611



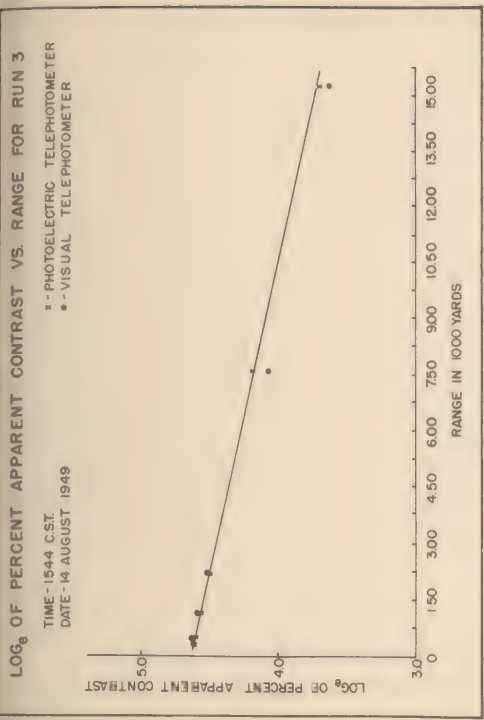
D-6615



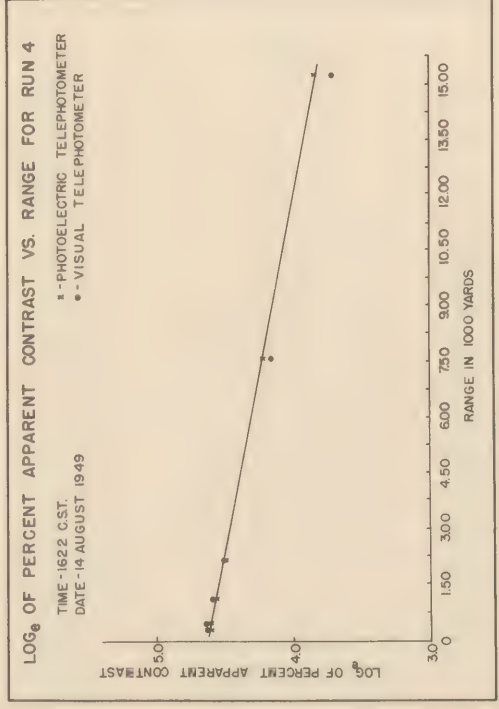
D-6641



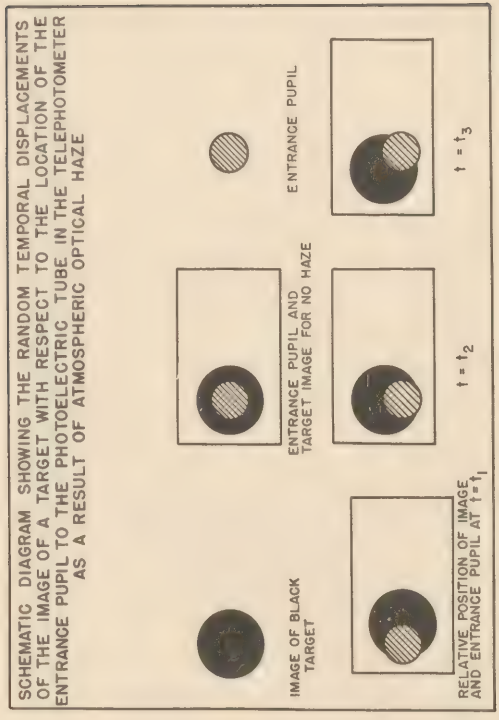
D-6642



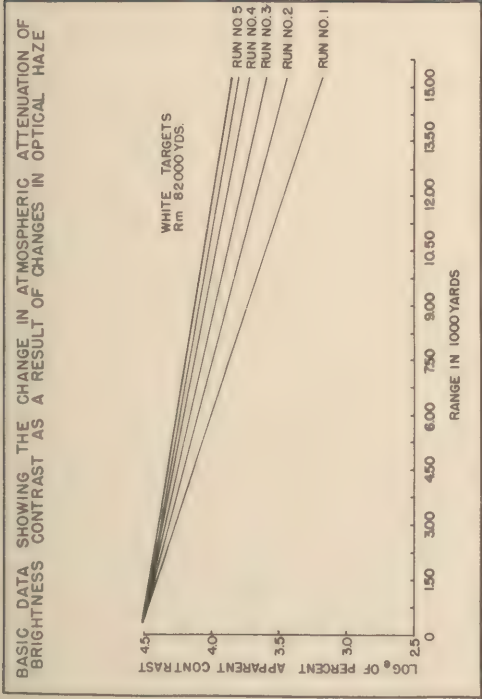
D-6643



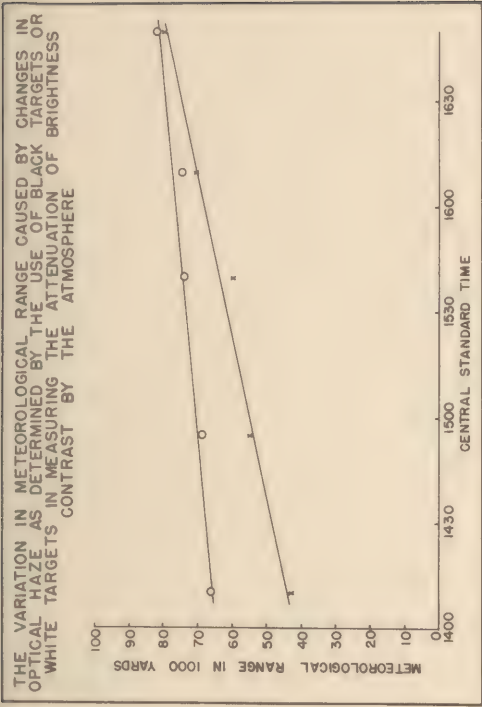
D-6644



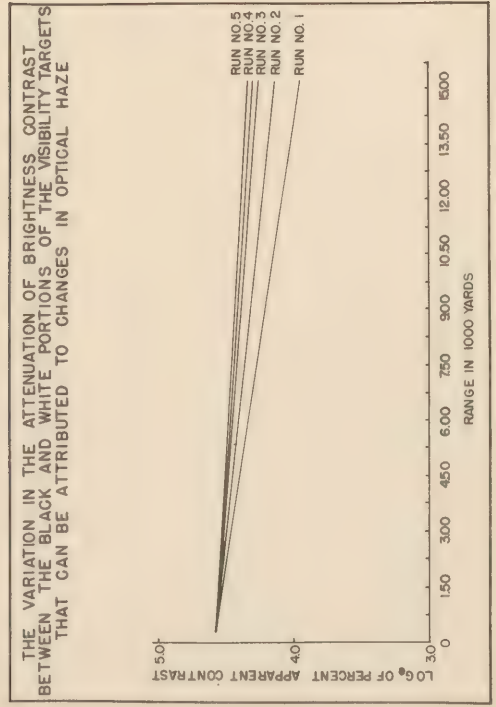
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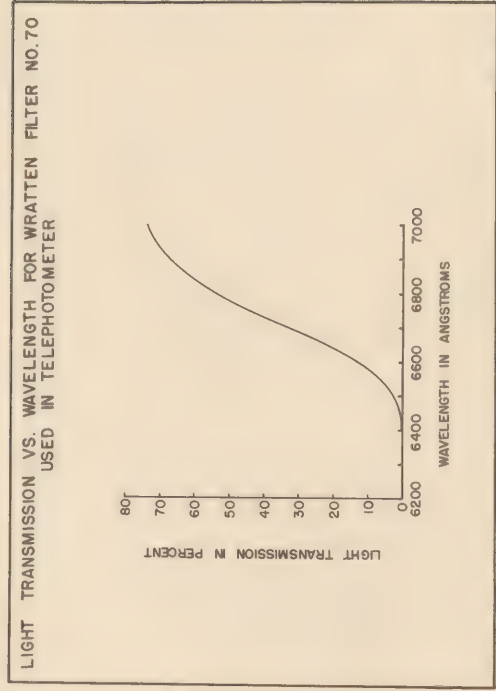
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D-6647

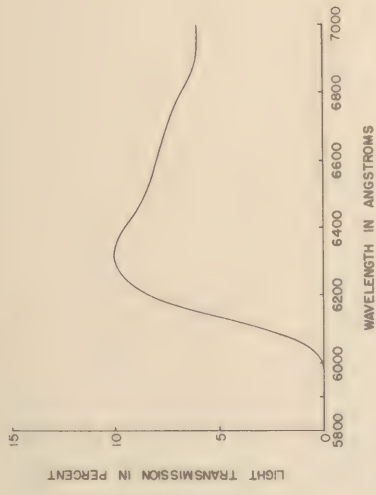


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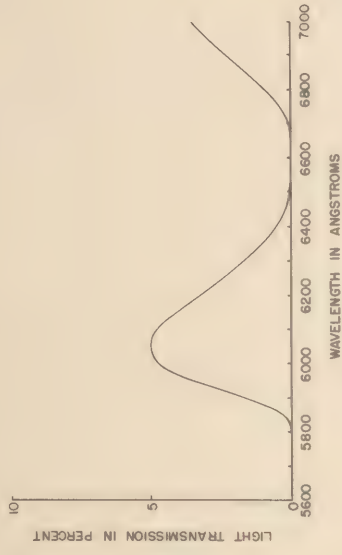
ORIGIN
8 NOVEMBER 1949
D-6798

LIGHT TRANSMISSION VS. WAVELENGTH FOR WRATTEN FILTER NO. 71A
USED IN TELEPHOTOMETER



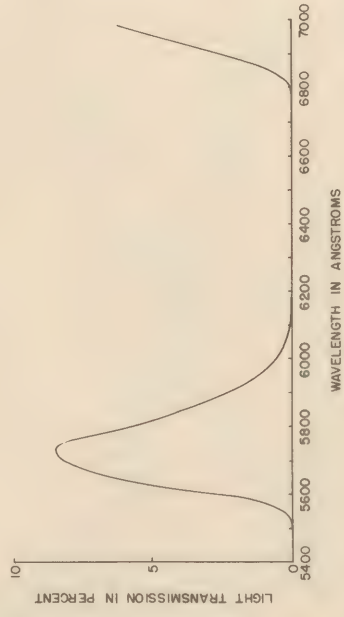
D-6799

LIGHT TRANSMISSION VS. WAVELENGTH FOR WRATTEN FILTER NO. 72
USED IN TELEPHOTOMETER



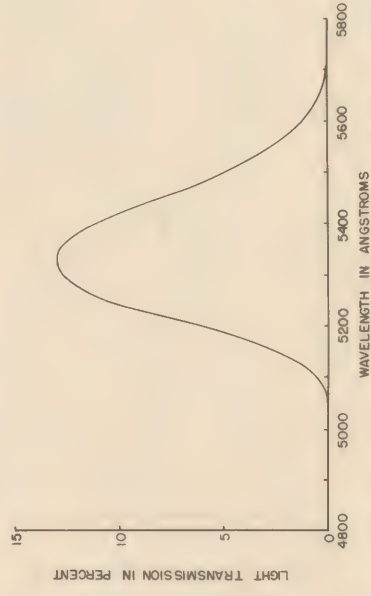
ORL/JIT
8 NOVEMBER 1949
D-6800

LIGHT TRANSMISSION VS. WAVELENGTH FOR WRATTEN FILTER NO. 73
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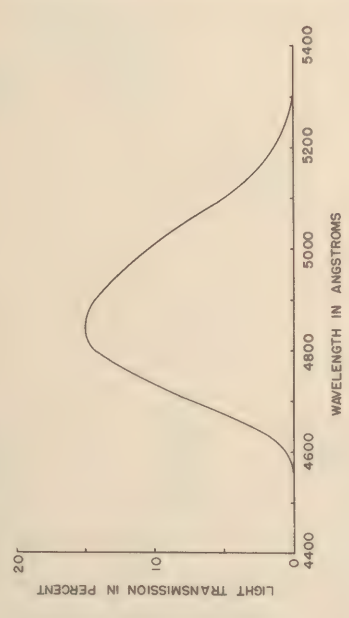
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8 NOVEMBER 1949
D-6801

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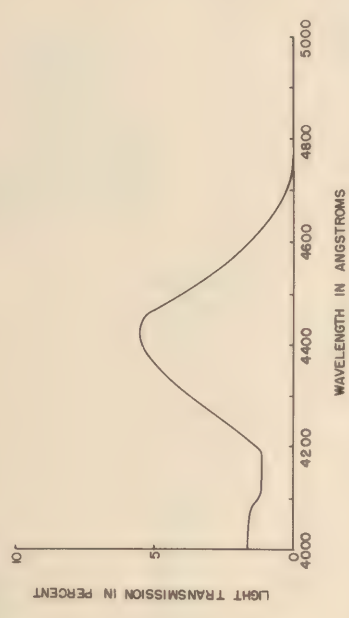
ORL/JIT
8 NOVEMBER 1949
D-6802

LIGHT TRANSMISSION VS. WAVELENGTH FOR WRATTEN FILTER NO. 75
USED IN TELEPHOTOMETER



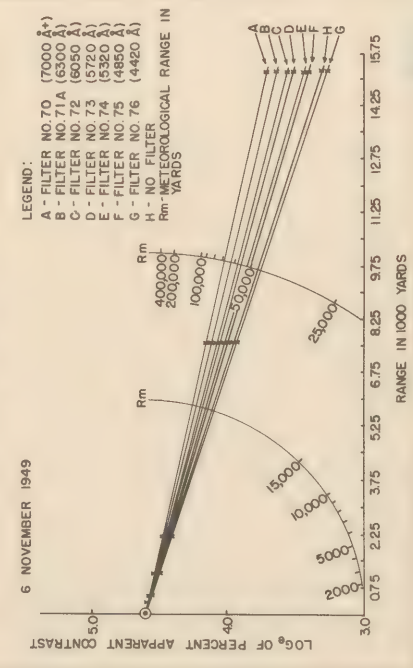
ORL/JUT
8 NOVEMBER 1949
D-5803

LIGHT TRANSMISSION VS. WAVELENGTH FOR WRATTEN FILTER NO. 76
USED IN TELEPHOTOMETER



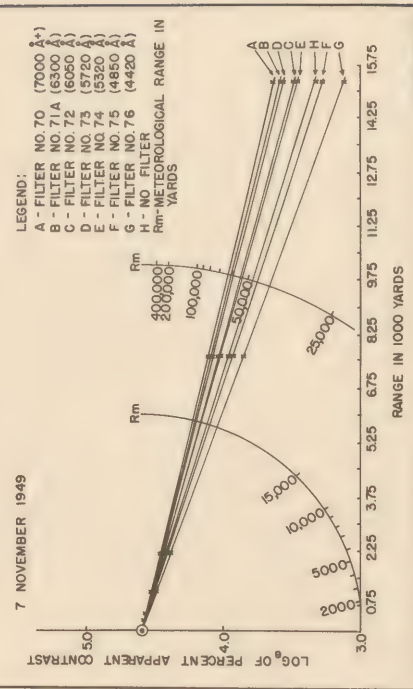
ORL/JUT
8 NOVEMBER 1949
D-5804

LOG_e OF PERCENT APPARENT CONTRAST VS. RANGE DATA OBTAINED
USING WRATTEN FILTERS



ORL/JUT
6 NOVEMBER 1949
D-5805

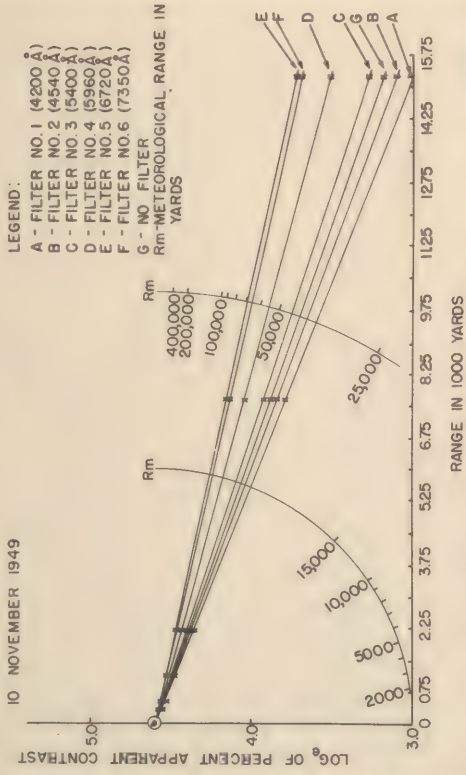
LOG_e OF PERCENT APPARENT CONTRAST VS. RANGE DATA OBTAINED
USING WRATTEN FILTERS



ORL/JUT
7 NOVEMBER 1949
D-5806

LOG₉ OF PERCENT APPARENT CONTRAST VS. RANGE DATA OBTAINED USING VARIOUS FILTERS

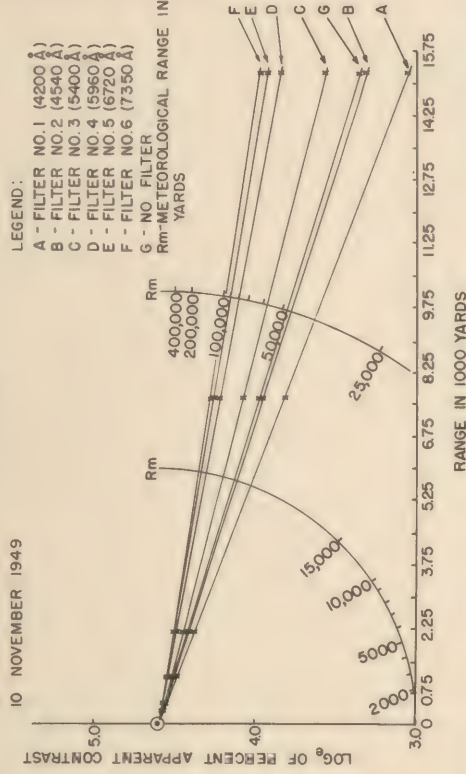
RUN 1



ORL/UT
10 NOVEMBER 1949
D-6827

LOG₉ OF PERCENT APPARENT CONTRAST VS. RANGE DATA OBTAINED USING VARIOUS FILTERS

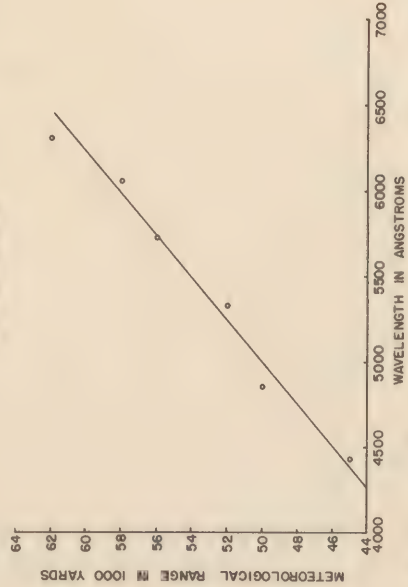
RUN 2



ORL/UT
10 NOVEMBER 1949
D-6828

METEOROLOGICAL RANGE VS. WAVELENGTH USING WRATTEN FILTERS

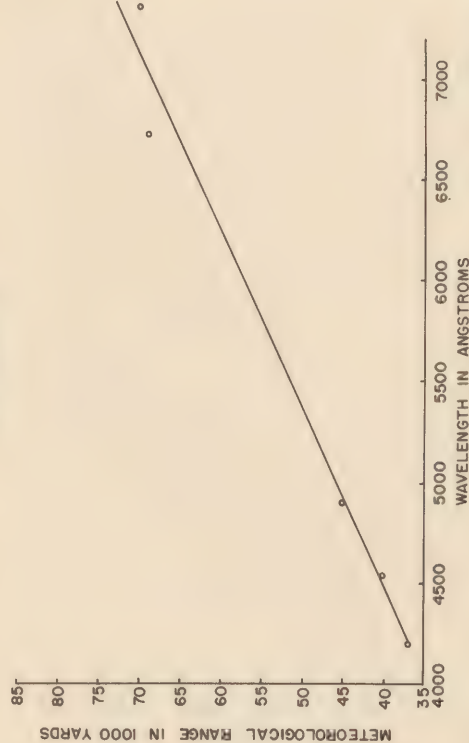
6 NOVEMBER 1949



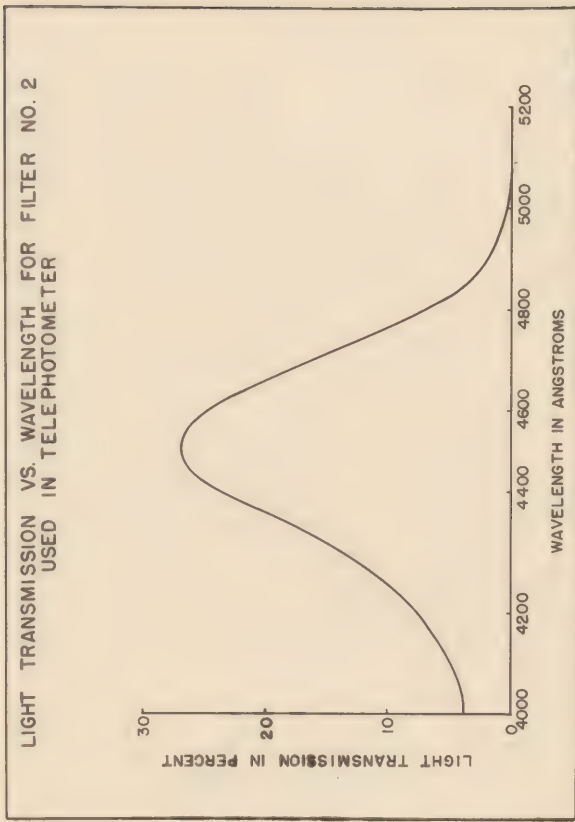
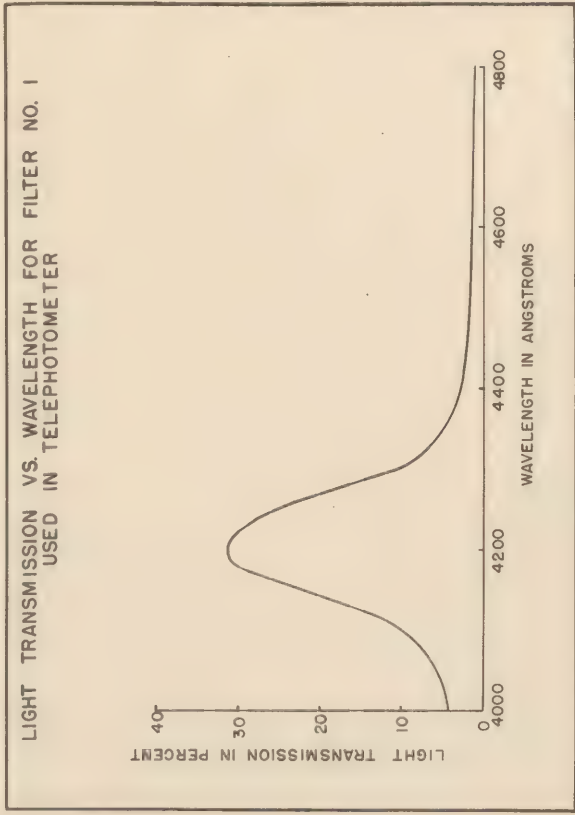
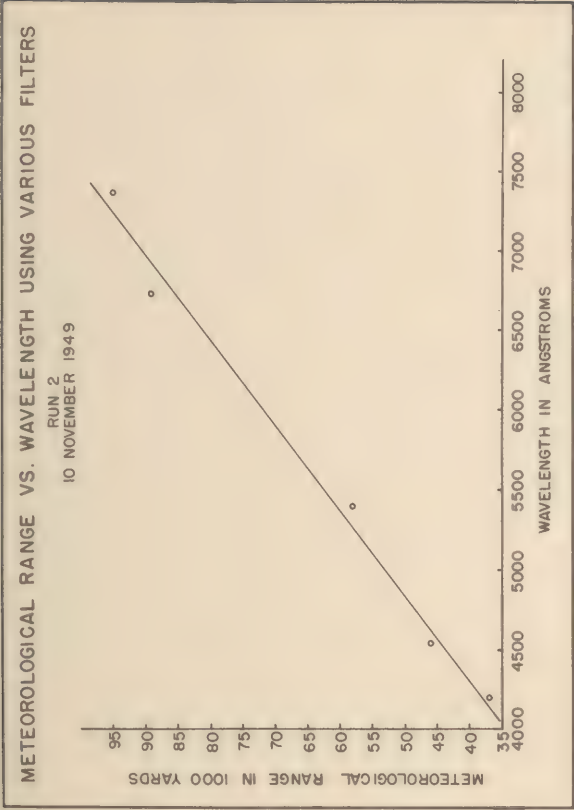
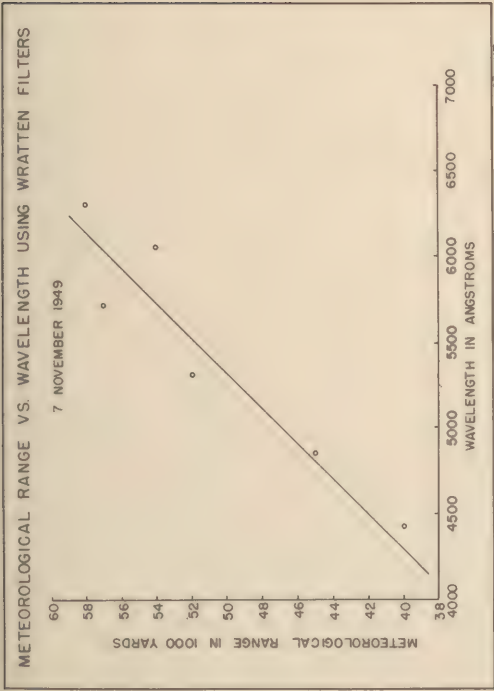
ORL/UT
6 NOVEMBER 1949
D-6805

METEOROLOGICAL RANGE VS. WAVELENGTH USING VARIOUS FILTERS

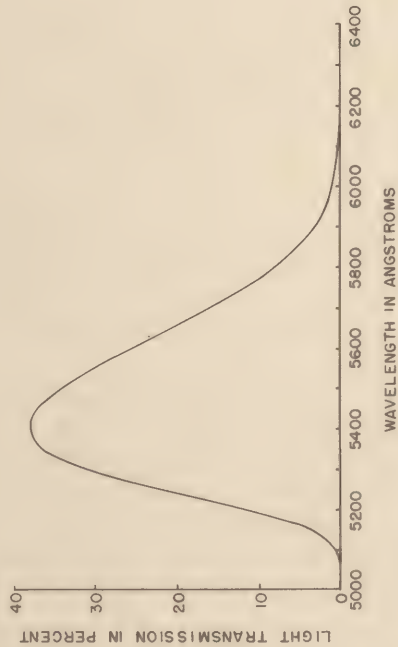
RUN 1
10 NOVEMBER 1949



ORL/UT
10 NOVEMBER 1949
D-6835

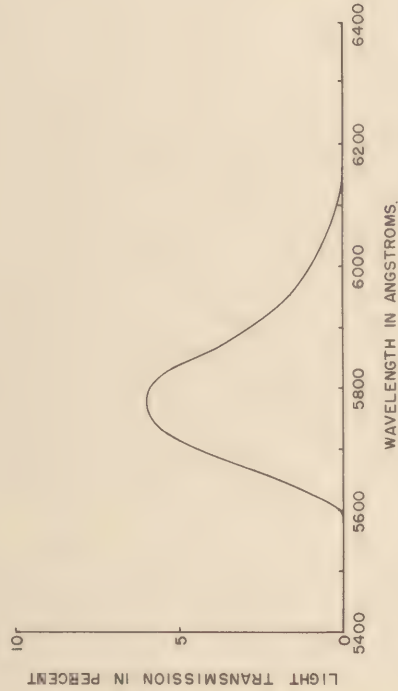


LIGHT TRANSMISSION VS. WAVELENGTH FOR FILTER NO. 3
USED IN TELEPHOTOMETER



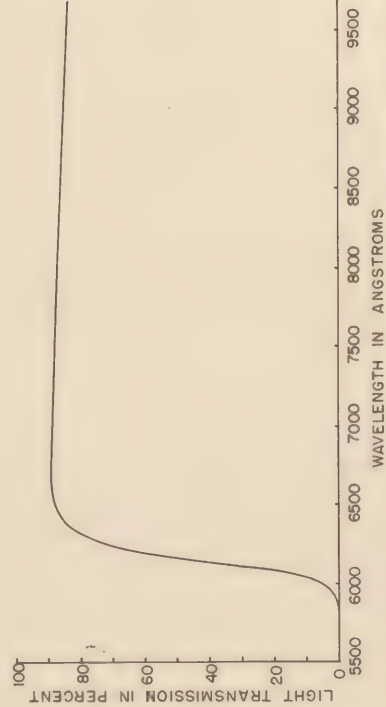
ORL/UT
10 NOVEMBER 1949
D-6831

LIGHT TRANSMISSION VS. WAVELENGTH FOR FILTER NO. 4
USED IN TELEPHOTOMETER



ORL/UT
10 NOVEMBER 1949
D-6832

LIGHT TRANSMISSION VS. WAVELENGTH FOR FILTER NO. 5
USED IN TELEPHOTOMETER



ORL/UT
10 NOVEMBER 1949
D-6833

LIGHT TRANSMISSION VS. WAVELENGTH FOR FILTER NO. 6
USED IN TELEPHOTOMETER



ORL/UT
10 NOVEMBER 1949
D-6834

MEASUREMENTS OF ATMOSPHERIC TRANSMISSION ACROSS CHESAPEAKE BAY

Richard Tousey

Naval Research Laboratory
Washington, D. C.

The transparency of the atmosphere can be determined with moderate accuracy during the daytime from observations of meteorological range using large dark and distant objects.¹ At night, however, this method fails completely. An estimate can be made by looking at distant lights but it is crude in nature. Accurate data concerning the transparency of the atmosphere at night are important in connection with work carried out at this laboratory, for example, field studies of near infra-red image forming equipment, optical communications systems, and the use of optical aids to vision. Prior to setting up the equipment to be described the method for obtaining atmospheric transmission at night used at the Naval Research Laboratory was to observe the meteorological range before dark and to assume that the atmosphere did not change transparency during the evening. Often times it was obvious that it did change.

The cases of particular interest to this laboratory were clear weather, with meteorological ranges between three or four miles and unlimited. In order to make measurements accurately under these conditions it is necessary to work over a long base line. A range over water was preferred because conditions over water are usually quite uniform and also because of the closer relation to Naval problems.

The Chesapeake Bay Annex (CBA) of the Naval Research Laboratory offers ideal conditions for work on atmospheric transmission. Its location is shown in Figures 1 and 2. It is about 30 miles from the Naval Research Laboratory and Washington, D. C. and is situated on a 100 foot high cliff at the edge of the bay. Complete facilities for research are available. In addition several small craft are attached to the station and permit carrying out field work between ships or between land and sea. At a distance of nine miles from CBA and directly across the bay is Tilghman Island. On the island there is a field station of CBA which consists of two 100 foot towers separated by a mile, a bunkhouse, dock and caretaker. The range across the bay between CBA and Tilghman Island was well adapted for use with equipment for the measurement of atmospheric attenuation at night in clear weather.

Mr. Carl A. Pearson, Naval Research Laboratory, Optics Division representative, lives on the base and is in charge of the optics research program at CBA. Mr. Pearson has been assisted in this work by M. Koomen, L. Dunkelmann, and E. Ockert.

I The Visual Telephotometer Installation:

Although the transmission of the atmosphere in spectral regions other than the visible is of considerable naval interest, the first equipment installed was designed to work in the visible portion of the spectrum. This decision was made because we believe that the visual transmission of the atmosphere is the parameter in terms of which atmospheric transparency should be specified, since it is the visual transmission which goes hand in hand with the everyday experiences of the Navy; it is in terms of this that practical thinking about visibility is generally carried out.

1. E. O. Hulburt, J. Opt. Soc. Amer. 31, 467, 1941.

~~RESTRICTED~~

The equipment set up to measure the visual transmission of the atmosphere consisted simply of several calibrated light sources of considerable intensity located on one of the towers at Telghman Island, and, at CBA, two Maxwellian view visual telephotometers. Electronic photometers were avoided for the sake of extreme simplicity.

The Maxwellian view telephotometers were constructed by simple modifications of existing photometers.² The modified MacBeth Illuminometer is shown in Figure 3. The Maxwellian view attachment consisted of the addition of an objective lens, cut from a spectacle lens, and slipped into the entrance tube of the illuminometer. The lens power was such that a distant light source was imaged on the observer's eye. As a result an out-of-focus patch of light fell on the retina and the lens and illuminometer field appeared to the observer to be of uniform brightness. A match could easily be made to the comparison field in the usual fashion. In addition it was necessary to place an aperture of small size directly before the eye. This was done to decrease the field of view and to make sure that the photometric match be unaffected by closure of the observer's pupil.

The second photometer is shown in Figure 4 and is basically a self-luminous low brightness photometer of the type developed at the University of Rochester.³ Here the comparison source was a phosphor excited by a radium containing gold foil. This was carried on the end of a rotatable arm and illuminated an opal glass which was the actual comparison field and was viewed in a small 45 degree mirror. The Maxwellian attachment in this case consisted of two objective lenses. The first imaged the distant source on an iris diaphragm and the second brought the beam to a focus on the eye. The iris diaphragm served as a variable field stop to reduce the field of view when the background was bright. Again, the final aperture had to be smaller than the observer's pupil, and small enough so that the photometric match made by the observer be independent of eye positioning. The entire unit was tripod mounted and is shown in Figure 5.

The light sources used were of two types: bare filament 1000 c.p. airway beacon lamps in pairs, and the 12 inch Navy searchlight with spread lens, beam c.p. about 90,000. One installation was made at the top of the Tilghman Island tower, about 100 feet above sea level, and a second at 15 feet. The telephotometers were located in the highest penthouse at the CBA at an altitude of 145 feet. The candle power of the several sources was measured in the laboratory for the particular direction used.

The photometers were calibrated against a reference light source operated at 2360° K color temperature, in accordance with photometric practice which is becoming widespread. The light sources on Tilghman Island were operated at a color temperature of 2850°K and Wratten 86B filters were placed in front of the telephotometers to reduce the color temperature to 2360°K. This resulted in more intensity than would have been obtained if the sources themselves had been operated at a color temperature of 2360°K.

This equipment was first placed in operation in 1947. Measurements have now been made on about 120 clear nights selected approximately at random and covering two years. Measurements were not attempted unless the meteorological range before sunset was at least four miles. The observed frequency distribution of atmospheric transmission is shown in Figure 6. The clearest night observed was 0.92 per sea mile. More than half the nights were better than 0.8 per sea mile. The lower limit

2. N. R. L. Report H-2303 "Some Devices for Measuring Atmospheric Attenuation of Light" by R. Tousey, H. Friedman, and E. O. Hulburt, June 6, 1944

3. O.S.R.D. Report; 1083; "Brightness of the Night Sky." Institute of Optics. University of Rochester, 1943.

~~RESTRICTED~~

of measurement was 0.4 per sea mile and was set by the equipment. This corresponded to a transmittance over the range of about $1/100000$. For transmittance values much less than this the 12 inch searchlight was invisible.

Records were kept of relative humidity, barometric pressure, temperature and other obvious meteorological conditions; as expected, there was no correlation with transmission.

It was of interest to determine, in so far as possible, whether the results were in agreement with the meteorological range observed during daylight hours. This was attempted only when atmospheric conditions appeared to be stable. Meteorological ranges were observed before sunset and after the following sunrise. Data were compared for days when the pre-sunset and post-dawn ranges were the same.

The comparison is shown in Figure 7. Here is plotted the exponential attenuation coefficient per sea mile (defined by $T = e^{-\sigma d}$) as determined by the telephotometers, against the meteorological range observed with the naked eye. The theoretical relation between $\sigma + V$ is given by $\sigma/V = 3.91$ for a 2 percent threshold contrast or $\sigma/V = 3.00$ for 5 percent contrast. Both relations are plotted on Figure 7. It can be seen that the observed points fall reasonably well on the 2 percent line, except at the longer ranges, where there seems to be a trend toward the 5 percent line. This can be explained qualitatively by the fact that for long ranges the distant shore line, which was the target observed, subtended a very small angle at the eye. No targets at more than 20 miles were available. The conclusion was that the agreement between the two methods, when conditions were reasonably stable, was satisfactory.

The question is often raised whether the transmission close to the water is the same as that along a path some distance above the water. Measurements were made to investigate this by comparing data taken on the lights 100 feet and 15 feet above the water. Ordinarily, the telephotometers were 145 feet above sea level and no difference was noted between these paths. On a few occasions the telephotometers were carried down to the water's edge, and still no difference was observed. These results show that under ordinary conditions stratification over this range is negligible. It is intended to investigate the matter further.

Twinkling of the light sources was frequently observed. Under these conditions an average photometric match was made. Settings were also made on the brightest and dimmest flashes. The ratio of brightest to dimmest setting was often 2 and occasionally as high as 4.

The precision with which the transmission could be measured depended on the experience of the observer. Under completely steady conditions a good observer repeated measurements of total transmission to 5 percent with the phosphor type instrument. The transmission per mile therefore was determined to an accuracy of better than 1 percent with this equipment, when there was no twinkling and conditions were very steady. With twinkling the accuracy was reduced and on repeated readings differences in transmission per mile sometimes reached 10 percent.

II The Photoelectric Transmissometer:

A photoelectric transmissometer developed by Dr. Paul H. Geiger of the Department of Engineering Research of the University of Michigan, under contract to the Bureau of Ships, was used together with the visual telephotometers on a number of nights. This transmissometer was designed for transmission measurements between

ships, or from ship to shore, for use in conjunction with test work on infra-red communications systems. The thalofide photocell was employed as the detector. Its spectral response extended from the visible to about 1.3μ with a broad peak at about 0.9 to 1.0μ .

The light source is shown in Figure 8 and consisted of a 500 watt lamp surrounded by a fluted glass cylinder which smoothed out the intensity distribution so as to be reasonably uniform in azimuth through 180° . It was intended to use two sources on a ship for 360° coverage. A rotating shutter located inside the glass cylinder chopped the light beam 60 times per second.

The receiving unit is shown diagrammatically in Figure 9. The thalofide cell was located within a 10 inch diameter aluminum reflector. The unit was designed to be hand held and aimed by the operator who looked through a reflector sight, shown on the top. A cable connected the receiver to the power supply and tuned amplifier. The indication was by means of a small neon lamp, also viewed in the reflector sight. In making a reading the attenuator knob was turned until the neon lamp just flashed. A second neon lamp was incorporated in the instrument and was operated in such a way that it served as a standard source. This was used for standardizing the receiver prior to the measurements.

The transmissometer was operated across the 9 mile range along with the visual telephotometers. In general the range of transmissions covered and the accuracy of setting was about the same as for the visual telephotometers. The thalofide transmissometer, however, gave higher values of transmission than the visual telephotometers. This is shown in Figure 10 where the difference between transmission per mile for the two methods is shown plotted against the visual transmission. This relation was different for different thalofide cells and obviously was connected with the fact that atmospheric transmission is somewhat greater in the infra-red than in the visible. This relation has not been studied in detail and depends on the spectral response of the particular thalofide cell. Since the relations between the two methods seemed to be unique, provided cells were not changed, it appears that the thalofide transmissometer, if calibrated against the visual telephotometers, would be capable of giving accurate measurements of visual transmission though this may not always be true. Use of filters to limit the response of the transmissometer to spectral bands in the infra-red, and visible is being investigated.

A platform in the Bay at a distance of 4000 yards from CBA has recently been completed and is being equipped with a set of light sources. With this short range it is possible to measure atmospheric transmission during conditions of much lower visibility and data can probably be obtained for transmittances as low as 0.02 per mile.

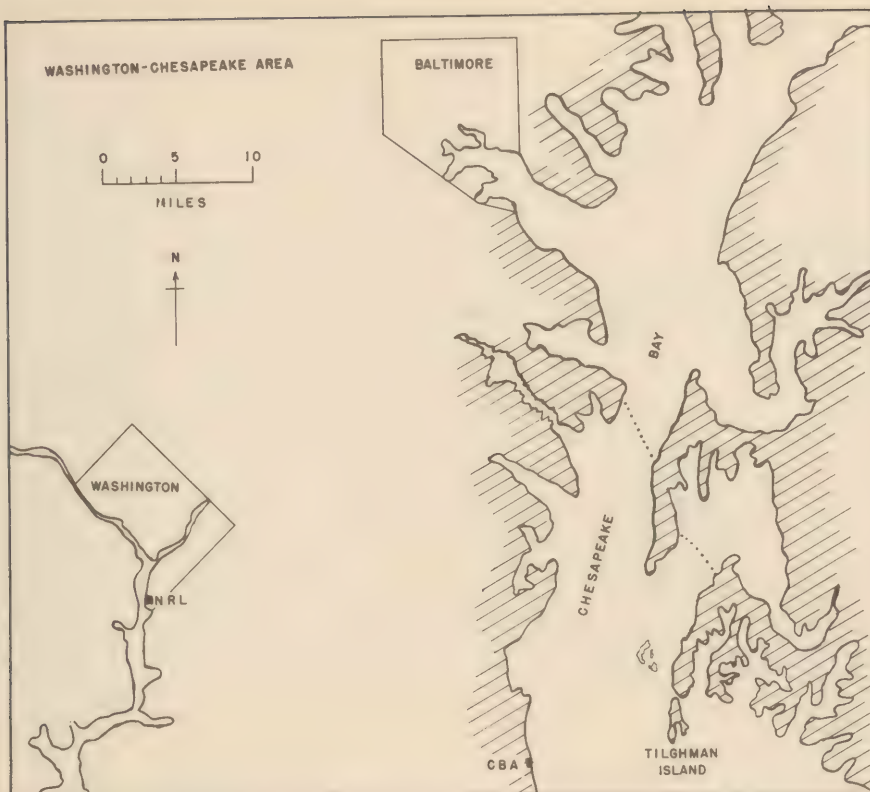


Figure 1. Location of the Chesapeake Bay Annex of the Naval Research Laboratory



Figure 2. Chesapeake Bay Annex of the Naval Research Laboratory

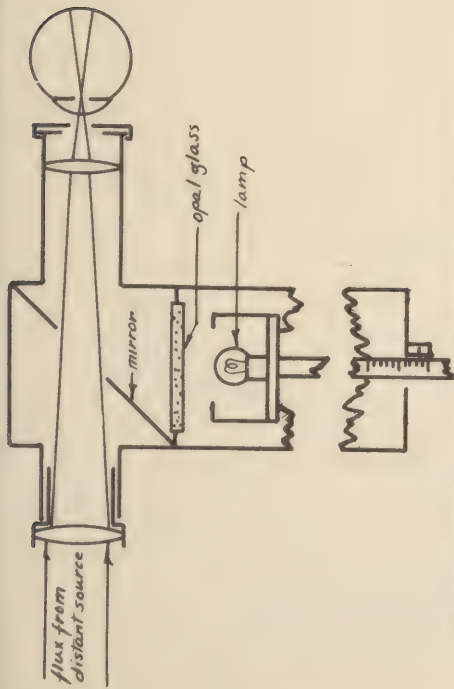


Figure 3. Maxwellian view telephotometer modification of Macbeth Illuminometer

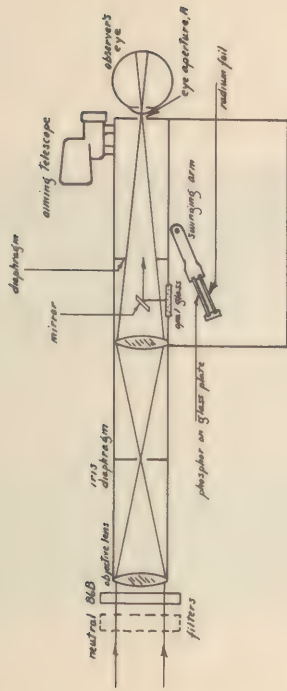


Figure 4. Phosphor type Maxwellian view telephotometer

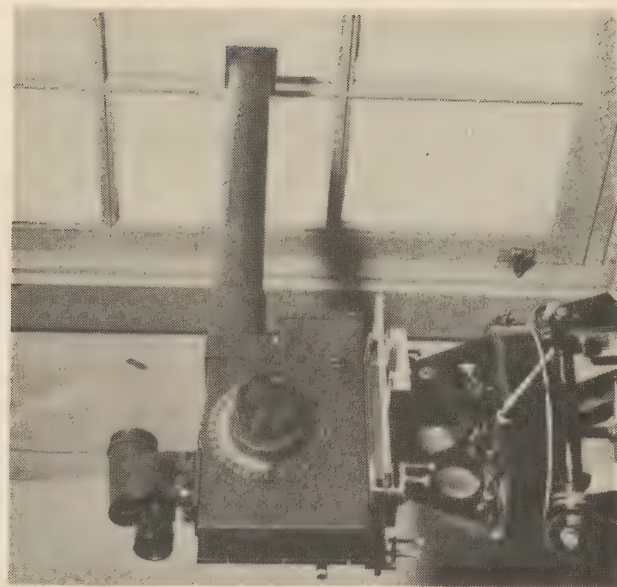


Figure 5. Phosphor type Maxwellian view telephotometer in observing position

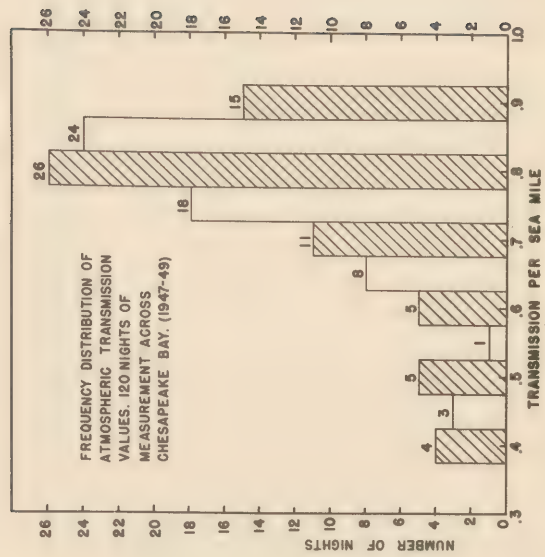


Figure 6.

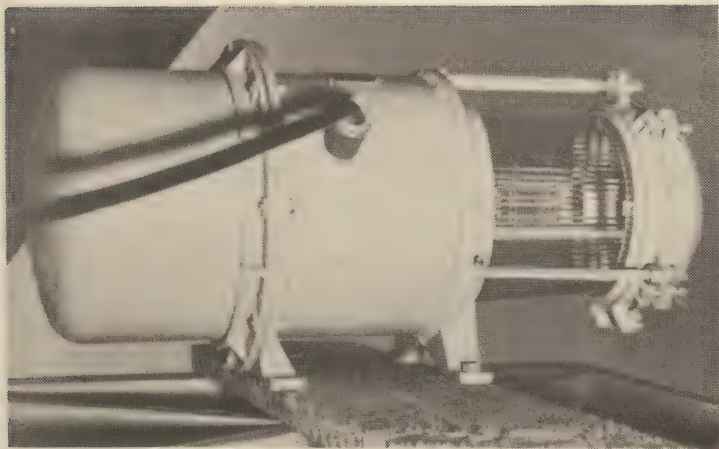


Figure 8. Light source for the University of Michigan thalofide cell transmissometer

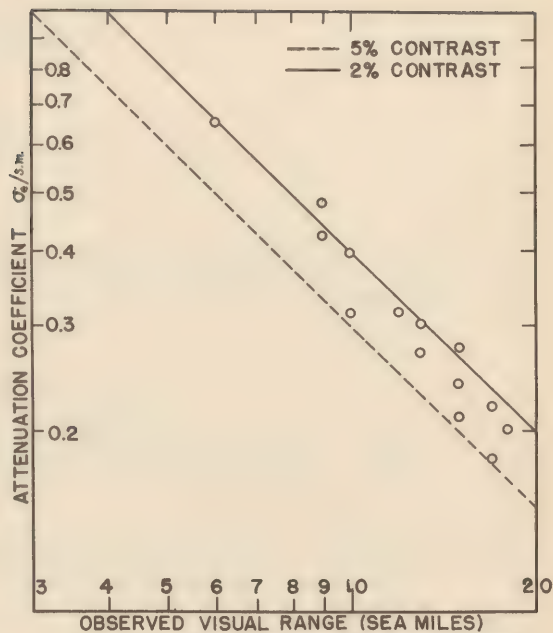


Figure 7. Comparison between observed visual range and measured attenuation coefficient

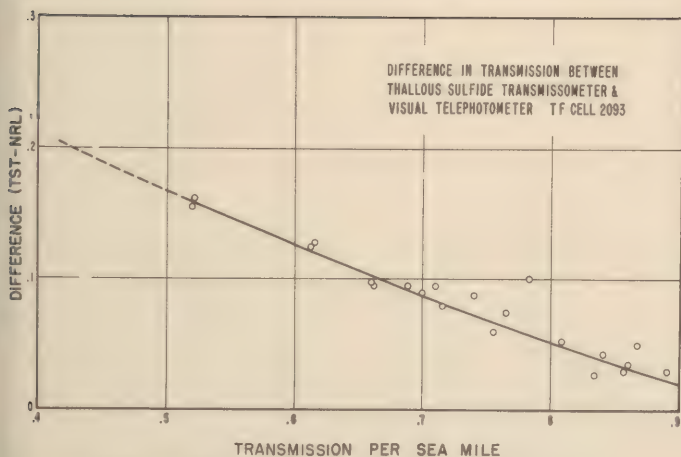


Figure 10. Comparison between the thalofide cell type transmissometer and the visual telephotometer

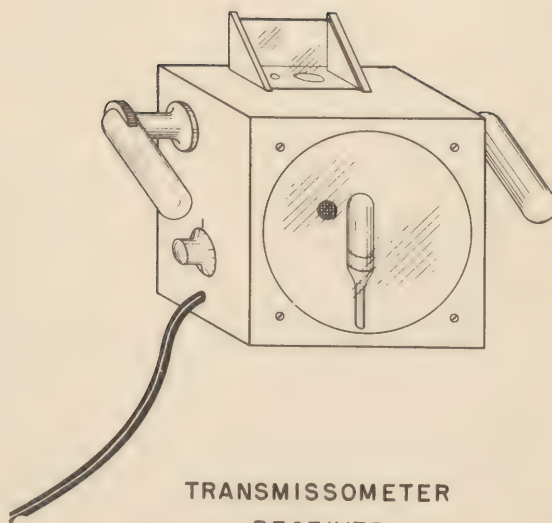


Figure 9. University of Michigan thalofide cell transmissometer receiver

ATMOSPHERIC ATTENUATION FOR WAVELENGTHS

2,500 to 10,000 ANGSTROMS

E. O. Hulburt
Naval Research Laboratory

Synopsis

A tabulation of the attenuation coefficients for wavelengths from 2,500 to 10,000 A for air varying from hazy to very clear was made by piecing together the data of four investigations:

- (1) Smithsonian Physical Tables, eighth Revised Edition, 1933, Table 767, columns 2 and 5; wavelengths 4,000 to 10,000 A.
- (2) A. Vassy, Theses, University of Paris (1941); wavelengths 4,265 to 2,200 A.
- (3) Optics Division, Naval Research Laboratory, now in progress; wavelengths in visible and ultraviolet.
- (4) W. E. K. Middleton, "Visibility in Meterology," Chapter 2, Second Edition, University of Toronto Press (1941); visible wavelengths.

The piecing together was fairly satisfactory because of two circumstances; (1) the Smithsonian and Vassy data agreed in absolute value over a small spectral region in which they overlapped, (2) Middleton's equation, established by him experimentally for 4,600 to 6,400 A, when extrapolated to 10,000 A, agreed with Smithsonian data out to 10,000 A.

The preliminary results are listed in Table 1 in which V is the daylight visual range and τ is the atmospheric attenuation coefficient defined by $i = i_0 e^{-\tau x}$ where i_0 and i are the intensities of a collimated beam of light in the wavelength interval $d\lambda$ entering and emerging from a column of the atmosphere x km in length. The values of τ for ultraviolet wavelengths below 3000 A in Table 1 are preliminary and may be changed to some extent when an investigation now in progress is completed. But the other values of τ will probably remain as given in Table 1.

A more complete report will eventually be published.

TABLE 1. Atmospheric attenuation coefficients.

λ	ν															
	10	15	20	30	40	50	60	70	80	90	100	120	km	sea	mi	le
A	5.4	8.11	10.8	16.2	21.6	27.0	32.4	37.8	43.2	48.5	54.0	65.0				
2500	3.31	2.50	2.25	2.00	1.85	1.76	1.68	1.64	1.60	1.55	1.53	1.50				
2700	2.20	1.67	1.30	1.18	1.05	1.00	.95	.91	.88	.85	.83	.80				
3000	1.45	1.00	.76	.53	.441	.376	.336	.310	.284	.266	.245	.219				
3300	1.08	.72	.56	.39	.31	.26	.226	.203	.185	.171	.155	.135				
3500	.92	.62	.48	.330	.261	.218	.186	.167	.150	.136	.125	.108				
3700	.79	.54	.41	.278	.219	.180	.155	.137	.123	.113	.103	.082				
4000	.66	.445	.342	.230	.175	.142	.122	.107	.097	.089	.082	.072				
4300	.55	.382	.292	.195	.145	.118	.100	.088	.079	.073	.066	.058				
4500	.50	.352	.285	.175	.133	.107	.090	.080	.072	.065	.059	.051				
4700	.47	.326	.250	.164	.125	.100	.084	.074	.066	.060	.054	.046				
5000	.44	.296	.228	.148	.114	.090	.077	.066	.059	.053	.047	.040				
5300	.41	.274	.210	.137	.104	.083	.069	.059	.053	.047	.042	.036				
5500	.395	.262	.198	.129	.098	.078	.065	.056	.050	.044	.040	.033				
5700	.381	.251	.190	.123	.092	.073	.061	.052	.047	.041	.037	.031				
6000	.370	.238	.178	.114	.085	.067	.056	.048	.043	.0375	.0335	.028				
6300	.355	.225	.168	.107	.079	.062	.052	.044	.039	.034	.030	.0252				
6500	.347	.218	.162	.102	.076	.060	.049	.042	.037	.032	.029	.0236				
6700	.340	.210	.156	.099	.073	.057	.047	.040	.035	.030	.027	.0222				
7000	.330	.200	.148	.095	.069	.054	.043	.037	.032	.028	.025	.020				
7300	.320	.193	.141	.090	.066	.051	.041	.035	.030	.026	.023	.019				
7500	.315	.188	.137	.087	.064	.049	.044	.034	.029	.025	.022	.018				
7700	.310	.183	.133	.084	.062	.048	.043	.033	.028	.024	.021	.017				
8000	.300	.177	.127	.080	.059	.045	.036	.031	.026	.023	.020	.016				
8500	.296	.167	.120	.074	.054	.041	.033	.028	.024	.021	.018	.014				
9000	.274	.158	.113	.068	.050	.038	.031	.026	.022	.019	.016	.012				
9500	.260	.148	.105	.063	.046	.030	.028	.024	.020	.017	.014	.011				
10000	.250	.140	.097	.058	.042	.0320	.026	.022	.0180	.015	.013	.010				

THE DETERMINATION OF SLANT VISIBILITY

H. S. Stewart
Naval Research Laboratory

Synopsis

It is assumed that the gradients of atmospheric composition are vertical, and, therefore, that the vertical transmission can be determined from measurements at slant angles, and vice versa. The light scattered from a portion of a searchlight beam is used as a source for atmospheric transmission measurements. If the flux density within the beam of the searchlight is symmetrical about the axis of the beam, then, under normal atmospheric conditions, the brightness at any point along the beam is symmetrical about the same axis. From the apparent brightnesses B_1 and B_2 of a selected portion of the beam measured at two surface stations at different distances from the portion of the beam but at the same angle to the axis, the vertical transmission T_0 to the portion is given by:

$$T_0 = (B_1 / B_2) \csc \theta_2 - \csc \theta_1$$

where θ_1 and θ_2 are the elevation angles of the lines of observation at the two stations.

The method was tested with a 36-inch searchlight and two modified Luckiesh-Taylor photometers for brightness measurements. On the night of April 14, 1949, at the Chesapeake Bay Annex, the vertical transmission to a height of 325 feet was found to be 97 per cent. The result was in agreement with visibility estimates made at the same time.

A more complete account is given in Naval Research Laboratory Report N-3484, "The measurement of slant visibility," H. S. Stewart, L. F. Drummeter, and C. A. Pearson, June 15, 1949.

PHOTOMETRIC SURVEY OF WORKING CONDITIONS FOR NIGHT VISIBILITY
DETERMINATIONS AT AIRPORTS*

by

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The night visibility at airports is at present determined by meteorological observers at the time of the reading of the thermometers. Visibility is taken as the distance at which a light, usually of unspecified intensity, can just be seen. The lights generally used are those put up in the vicinity of the airport for other purposes and not especially for visibility determination. Since the number of useful lights is restricted at most airports, often for a given visibility no light at exactly the same distance exists. In that case an estimate is made as to how much brighter the light is than the background and the visibility is deduced therefrom. Besides other factors the background brightness and the state of adaptation of the observer are determining factors in visibility measurements. The background brightness can be measured directly. The state of adaptation of the meteorologist's eyes can be deduced from the luminance to which he has been exposed before his visibility determination.

Methods

To achieve the highest possible accuracy, all luminance measurements for this report were done by the same observer (the author). As photometer the Schmidt and Haensch Universal Photometer, Model No. 1, was used. It was calibrated by comparison with standard light sources of the National Bureau of Standards, Washington, D. C.** The calibration readings used during the later measurements were done by the observer himself to use his particular spectral sensitivity. For each group of four measurements the current for the instrument was checked on a precision ampere meter.

Luminance determinations were made at 14 airports. The first measurements to be taken were those of the luminances to which the meteorological observer is exposed during his work time in the office. The luminance of a piece of paper of 70 percent reflectivity on the desk of the observer was measured under prevailing illumination. Since it was assumed that this luminance did not vary considerably, this adaptation luminance was determined once at each airport. If various work places with different illuminations were used, then measurements were taken at these several places. For each single determination the arithmetic mean of the four readings of the instrument was taken. The background luminance was measured near the horizon which is where the actual lights for visibility determinations were found. Mostly, it was the region between 0 degrees and 5 degrees above the horizon. The measurements were taken from that place at each airport where the observer was accustomed to making the visibility observations. At civilian airports that was on top of the operations building, and at most military airports it was on the ground near the thermometer housing. At most airports the background luminance could not be measured in all directions because obstructions such as hills or buildings blocked the view. Background measurements were made by forming an image of the background with a telescope system inside the photometer. The illumination on the hori-

* The work reported here was done at the request of the Armed Forces-NRC Vision Committee according to suggestions by Mr. W. E. K. Middleton.

** The author expresses gratitude to Mr. Ray P. Teele for this valuable help.

zontal surface at the place of the meteorological observation was measured by means of a diffuse reflecting surface of gypsum, reflectivity of which was determined by Mr. R. P. Teele of the National Bureau of Standards to be 0.96.

The measurements of illumination and background luminance were taken at close intervals during dusk and dawn and at considerable intervals during the night. For each single determination in one direction, four readings of the instrument were taken and the arithmetic mean determined.

Results

The results are given in milliapostilbs (masb) for luminance and in millilux (mlx) for illumination. One masb (or 1/1000 apostilb) is equal to 0.1 microlambert, or 9.3×10^{-5} footlamberts. One mlx (or 1/1000 lux) is equal to 0.0000929 foot-candles. These two units belonging to the metric system were chosen because an illumination of 1 mlx on an ideally diffuse reflecting surface gives the luminance of 1 masb. Thus, illumination and luminance can be given in the same coordinate system and the brightness which a surface of given reflectivity would have under the measured illumination can be easily visualized.

Figure 1 shows the result of measurements on three small military airports: Arcata, California; Kirtland Air Force Base near Albuquerque, New Mexico, and Smoky Hill Air Force Base, Kansas.

Figure 2 gives the results obtained at six large military airports: Mitchell Air Force Base, New York; MacDill Air Force Base, Florida; Hamilton Air Force Base, California; Lowry Air Force Base, Colorado; Scott Air Force Base, Illinois; and Randolph Air Force Base, Texas.

Figure 3 shows measurements at five large city airports: National Airport, Washington, D. C.; La Guardia Field, New York; King County Airport (Boeing Field), Seattle, Washington; Municipal Airport, Los Angeles, California and Lambert Field, St. Louis, Missouri.

Figure 4 gives the range of the different measurements for the three groups of airports.

Discussion

Figures 1, 2, 3, and 4 show that the pre-adaptation of the meteorological observer to bright light in his office occurs mostly in luminances which range between 100,000 and 1,000,000 masb, (10,000 and 100,000 microlamberts).

Since at all airports visited the office of the meteorologist was very near to the observation point, only a walk of less than a minute between them was necessary. With the bright-adaptation luminance in the measured range, the average normal in one minute is adapted to a luminance of 350 masb, (or 35 microlamberts). For the average normal it takes about 6 minutes to reach 35 masb (3.5 microlamberts) and about 10 minutes to reach 25 masb, (2.5 microlamberts) and that is very near to the threshold of the cones. Though I have seen the meteorological observer remain more than 10 minutes outside his office for observing a balloon, I have not witnessed observers taking that much time for ordinary visibility determinations. Many of the background luminances measured, at least at smaller airports, give values far below those to which the meteorological observer is adapted at the time of his observation. His sensitivity is, therefore, not at the optimum for his task. This considers the

after-effect of the bright adaptation in the office only. On many airports there was found a considerable illumination on a horizontal surface. Since the observer has, with the white painted thermometer housing or a piece of paper for notes, highly reflecting surfaces near him, this illumination constitutes a considerable simultaneous glare. The local illumination retards the meteorologist's adaptation by glare from illuminated surfaces and by after images which he gets from looking at the light sources. At civilian airports this glare is often caused by brightly illuminated advertising signs. At the military airports big reflector lights used to illuminate the work and traffic area in front of the operations building bring about glare. This local illumination by glaring lights also affects the background luminance. It is rarely justified to call this luminance surrounding a light target "background" luminance, or "sky" luminance because at many airports visited, during the time the big lights were burning, much of the "background" luminance is produced in the immediate vicinity of the observer by scattered light from lamps near him. Yet the term "background" luminance was used for convenience.

It is, therefore, reasonable to conclude that at present many meteorological observers do visibility determinations in a state of adaptation which is far from optimum and which differs essentially from that of a pilot in a correctly lighted cockpit, for whom the visibility observations are made.

There are several possible means to improve the dark adaptation of the visibility observer:

1. Perform the visibility determinations from a place which is less exposed to glaring light; for instance, near the touch down point of the aircraft, thereby more nearly equaling the visibility conditions to which the pilot is exposed.
2. Wear neutral gray filter glasses of 10 to 15 percent transmission for the last 5 minutes the observer stays in the brightly lighted office. (Such glasses should not be used outside at night.)
3. Specify a minimum time which must elapse after leaving the brightly lighted office before visibility determinations will be made. Six (6) minutes would be a suitable time, and when dark goggles are worn in the office as suggested in paragraph 2 above, the minimum outside dark adaptation time could be shortened to three (3) minutes.
4. Decrease the local illumination during the visibility observation. This does not mean total blackout, but the elimination of light sources not actually necessary for safety and a shielding of light sources which are necessary for operations.

While the changes as suggested in paragraph 1 are effective, they might be difficult to accomplish. However it should be practicable to introduce any one of the changes in procedure suggested in paragraphs 2, 3 and 4 or to effect a combination of them.



Fig. 1 Luminescence and Illumination at Airports.

- Inside adaptation luminance in millipostilb.
- ↓ Illumination on a horizontal surface, in millilux.
- Background luminance, in millipostilb.

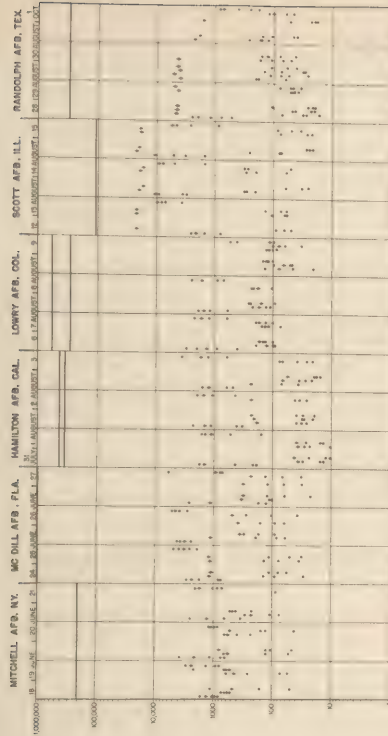


Fig. 2 Luminescence and Illumination at Airports.

- Inside adaptation luminance in millipostilb.
- ↓ Illumination on a horizontal surface, in millilux.
- Background luminance, in millipostilb.

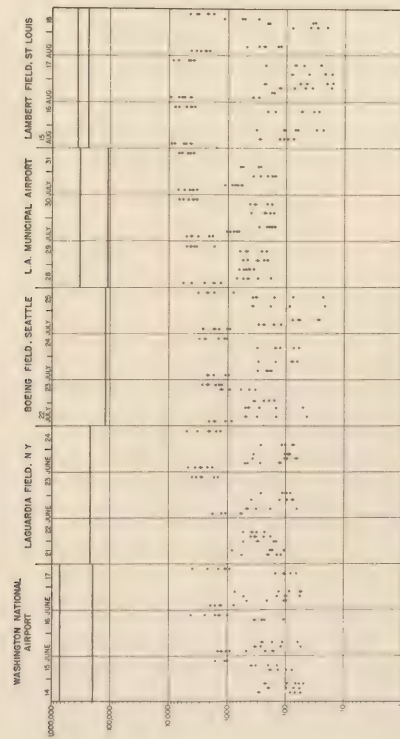


Fig. 3 Luminescence and Illumination at Airports.

- Inside adaptation luminance in millipostilb.
- ↓ Illumination on a horizontal surface, in millilux.
- Background luminance, in millipostilb.

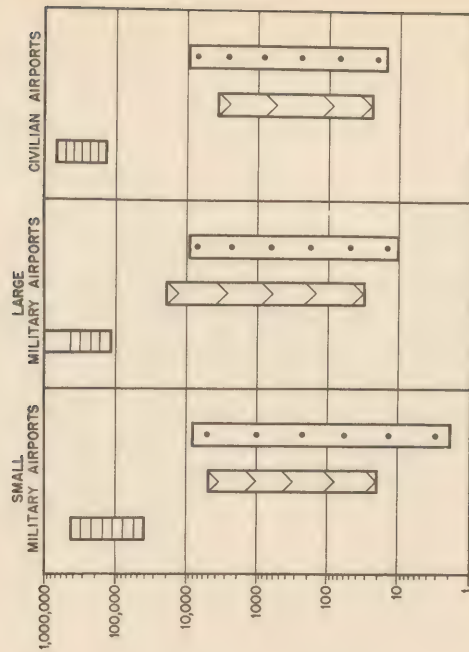


Fig. 4 Range of Brightness and Illumination at Airports.

- Inside adaptation luminance, in millipostilb.
- ↓ Illumination on a horizontal surface, in millilux.
- Background luminance, in millipostilb.

THE SPECIFICATION OF SUN GLASSES

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I Introduction

In 1945 sun glasses for general issue to all personnel except aviators were specified to be plastic, polarizing, 10-15% transmission, and neutral in color. There were no specifications against ultra-violet nor infra-red. At the same time, specifications for aviation sun glasses (worn by aviators) required ground-and-polished glass, of about 12 to 18% transmission, with certain ultra-violet and infra-red absorptions, and of three specific colors, an amber called "Rose-smoke", a green glass comparable to Rayban, Calobar, or Willsonite, and neutral gray, such as is found in Houze #1911 smoke, and Bausch and Lomb Neutral.

II Experimental background.

A. War Period.

There was a certain body of research in back of these specifications, which were essentially dependent upon the recommendations of this Committee. The most important single research was that of the late Dr. Selig Hecht, who showed that the exposure of the retina to excessively bright sunlight resulted in a subsequent loss of dark adaptation. Dr. Hecht recommended the use of sun glasses by all personnel who anticipated any night duty, in order to prevent or minimize this loss. The 10% polarizing sun glasses were designed and procured with his research in mind. Dr. Brant Clark, at Pensacola, showed that these polarizing sun glasses were approximately adequate in supplying the protection needed, by comparing the visual threshold of subjects, one of whose eyes remained protected by the sun glasses, while the other eye was exposed, since he cut the plastic lenses out of one eye with scissors. Dr. Dean Farnsworth, at New London, showed that the neutrality of the plastic polarized sun glasses was not as effective as had been anticipated, which was explained at that time by the probability that he did his work with a batch of lenses dyed earlier than the glasses then being procured.

II Experimental Background.

B. Post war period.

Research on problems allied with sun glasses has been continued since the war. Dr. Ernst Wolf, at Harvard, has shown that the small amount of ultra-violet light emitted by certain fluorescent lamps causes a loss of subsequent dark adaptation, greater than that caused if this amount of ultra-violet is removed. Although the difference is small, Dr. Wolf feels that it is significant, and that sun glasses should include some ultra-violet protection. Although we are not personally convinced that he has proven his point, we are in sympathy with his effort.

A considerable amount of work has been undertaken at the Temple University School of Medicine, in the Department of Ophthalmology, upon the need for and effectiveness of sun glasses. Of course, this work is primarily directed toward the civilian use of sun glasses, from a public health point of view. Nevertheless, our conclusions can, we believe, be validly applied to the problems of military sun glasses.

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The first study here undertaken was concerned with the effect of the color or tint of sun glasses on the perception of color by the wearer. In effect, this problem is involved with the phenomenon of "color constancy." The ICI Standard Observer predicts when two colors will match, under an illuminant of known spectral distribution. But the ICI Standard Observer does not predict what color such objects will be for a real observer. In a certain sense, it may be impossible to predict what color an object will be to a particular individual, but the phenomena of agreement in color naming, and in the apparent colors that objects have under different illuminants, permit us to predict somewhat, how colors will appear. Thus, two blue objects can be predicted to match by computation, but they may have been predicted to be greenish. They may actually appear blue. Hence, if we were to predict, by the ICI Standard Observer, the color coordinates of a pale blue object through a green rayban sun glass lens, we would find the coordinates in a region of mathematical color space generally assigned to green objects. But upon experimentation, we might find that the object is still blue in appearance. This would be to find that the phenomenon of "color constancy" had entered the situation.

Experimentally, it was found, in the report on Project NR 142-565, contract N8 onr 560, that sun glass lenses of the various colors described as Rayban, Calobar, Rose-smoke, and Solarex (a blueish lens), retain a very considerable amount of "color constancy," and that object colors are not as greatly disturbed by the tints of these lenses as the Standard Observer would have predicted. In the experimental work there reported, it was found that the color constancy was not complete, but that it was partial. For the purpose of the civilian use of sun glasses, therefore, it is concluded that any of the colors available in the market, as "essentially neutral" colors, are not prejudicial to color vision for a degree that is significant, and are not as distorting to object color perception as would have been predicted by their computation according to the Standard Observer. For general issue sun glasses, therefore, we conclude that it is not necessary to insist upon rigid specifications of "neutrality," or non-selectivity, in the spectral transmission.

On the otherhand, in the case of personnel who are required by their duties to be very sensitive to small color differences, as aircraft pilots, the incompleteness of "color constancy," however close it may be, may be inadequate, and such personnel must be supplied with sun glass protection which cannot prejudice their color vision at all. Such persons should be supplied with glasses of neutral gray appearance, which have as little spectral selectivity as can be produced. In this case, of course, the tolerances of selectivity at the extreme (violet and red) ends of the spectrum are of somewhat less importance than selectivity in the central blue, green, yellow, and orange portions of the visible spectrum.

In addition to the observations of color-constancy, this report was also concerned with certain problems of liminal hue differentiation. Here we found, for example, that the effect of Rose-smoke in changing the differentiation between colored papers (as between yellow snow and blue shadows, to light snow and dark shadows), was not particularly helpful in the discrimination of the actual samples. In other words, the shift from hue contrast to brightness contrast gave no advantage. It is believed that when such shifts are to be contemplated, for special and specific circumstances, that "special-purpose" glasses should be selected or developed, which will accomplish the desired discrimination in a most noticeable fashion, at the expense of less essential perceptions of color within the particular situation. A good example of this lies in the dichroic filters developed toward the end of the war, which were designed to permit the maximum perception of the strontium flame of

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tracer fire control. These dichroic lenses grossly distorted object-colors, but permitted a phenomenal increase in the range of recognition of the tracer flame.

A third portion of the cited report concerned itself with preparation of a means of specifying "essential non-selectivity" in sun glasses. In the specifications An-G-22-a, a very accurate method of this specification is offered in the "daylight duplication index." However, the method of computation is arduous, and liable to gross misinterpretation from small arithmetrical error. As a substitute, perhaps, a graphical interpretation of non-selectivity which is somewhat quicker and easier to accomplish is offered in the report. This method, called the Index of Color Constancy, might be a useful means of specification for Aviation Sun Glasses.

Of more importance, from the civilian consumers' point of view, is the study of the effect of sun light exposure, on the beach at Atlantic City, upon retinal sensitivity. This work is an extension of the work of Hecht, and that of Clark, upon the terminal visual threshold. It was our purpose to determine if the loss of sensitivity found by these authors could be found and measured at photopic (cone) brightness levels. The work was done with members of the Atlantic City Beach Patrol as subjects. These men were tested for retinal sensitivity with a test of contrast-visual acuity perception, and with tests of critical flicker frequency at a brightness near one foot lambert. This brightness approaches the brightness of certain conditions of night driving, for example. It was found that the depression of retinal sensitivity could be equally well demonstrated at such cone levels, and that therefore the effect of loss of retinal sensitivity predicted at the threshold of rod vision could be interpreted as a comparable loss at low cone levels. This loss, which will be described in more detail in a later paper, amounts to about $1/3$ log unit, or a loss of retinal sensitivity to light of about $1/2$. In extreme cases, the loss amounts to 1 log unit, or a loss of sensitivity to $1/10$ of the useful brightness of the illumination. The effect of the loss must be interpreted in terms of the various visual limens of contrast-and-acuity as if the illumination were comparably reduced. At high brightnesses, therefore, there may be no serious or noticeable reduction of visual perception, but as the brightness is decreased, as in night driving, or working under conditions of minimal illumination or inadequate illumination, the loss of retinal sensitivity becomes increasingly distressing.

Sun glasses, as at present sold in the open market, are of quite inadequate density, and are not, therefore, effective in preventing loss of retinal sensitivity, although they may supply a sensation of comfort to the wearer. In the study at Atlantic City, it was found that such sun glasses, when purchased by the life guards, were not effective, even when worn quite regularly. In recognition of this fact, during a second summer of the continuance of this study, special sun glasses were prepared whose transmission was between 10 and 20%. It was found that the lower transmissions were of some help, but that the protection was not complete. It is also noteworthy that the darker glasses were not unpopular with the men, but that they were preferred to the less dense ones that they could purchase themselves. This is in line with the observations made during the war, of rather sporadic nature, that 10 and 4% sun glasses would not be rejected by the wearers under conditions of extreme brightness.

A third problem investigated in this department has been the studies of the optical qualities of sun glasses. Of these, the least amount of time has been afforded to polarizing sun glasses, since these represent such a small part of the volume of civilian purchases. Since polarizing sun glasses were recommended

by this Committee during the last war, and were used extensively by the armed services, certain conclusions concerning them should be considered, even in the absence of experimental study. Reports of headaches, associated with the wearing of polarizing sun glasses, were not common, but were not absent, in military personnel. Civilians, on the other hand, report discomfort from the wearing of polarizing sun glasses with somewhat greater frequency. A little consideration of the effect of the polarizers on the two retinal images, which can be easily confirmed by looking at reflections of the sun in disturbed water or at highly polished automobile surfaces on the street, indicates that there is liable to exist a considerable local brightness difference between the two retinal images, which is probably due to the difference in visual direction of certain bright elements in the object. Since polarizers are very sensitive to small differences in the angle of polarization of light reflected from bright objects, the binocular images may be composed of two monocular images which are alike in most respects, but which contain small elements of great brightness difference in corresponding areas. Such a condition is one of the best methods available to arouse the condition of "retinal rivalry," a binocular phenomenon in which the portions of the two images are alternating as visual stimuli, instead of fused into a single binocular perception. This retinal rivalry is closely associated with binocular imbalances, as phorias, and with failure of binocular fusion, as suppression. When the binocular stimulus is strongly prejudiced towards such disorders of binocular function, it is easy to appreciate the discomfort of polarizing sun glasses for persons of inadequate or borderline binocular function. Since military personnel is moderately screened by the initial medical examinations, and by their general youth and good health, fewer complaints against polarizing sun glasses should be expected in the military than among civilians. It is not feasible, however, to provide all potential wearers of sun glasses with an ophthalmic examination which would, in effect, permit the prescription of polarizing sun glasses, and therefore the general issue of polarizing sun glasses cannot be recommended.

Of greater practical importance has been the study carried out in this department on the effect of method of manufacture on the optical quality of sun glasses, which was reported by the writer to the Optical Society of America at the meeting in Buffalo, in October, 1949. There are three methods of preparing glass for sun glasses, (1) grinding and polishing a blank to the finished curve of the sun glasses, (2) grinding and polishing sheet, or thin plate glass, and bending the sun glass lenses after they are cut out of the sheet, and (3) drawing tinted glass in a relatively flat sheet, cutting out the lenses, and then bending them to curve. In a study of visual resolution of groups of 27 and 40 subjects, looking at a checkerboard type of resolving power target through all three types of sun glasses, monocularly and binocularly, it was found that there were no significant differences in the visual resolution through any of these three types. In effect, this amounts to saying that there is no advantage to the wearer, nor no disadvantage, regardless of the method of manufacture of his sun glasses, at least in terms of noticeable visual resolution. Further studies were then undertaken on the nature of the optical errors of the drawn and bent sun glass lenses. It was found that this method of manufacture imposed certain errors on the finished product, in terms of prism, spherical, and cylindrical dioptric power, and certain reduction in the resolution of critical targets viewed through a telescope before which the lens was placed. The amount of dioptric error found in the lenses was very small, however, being in the examination of about 5,000 pairs, less than 1/4 diopter in all cases, and less than 1/8 diopter in over 90% of the cases. Since the limit of accuracy in ophthalmic prescriptions for eye glasses is of this same order, it is felt that such errors can not have any effect on the vision of the wearer. With regards to the reduction of resolving power, it was found that

this reduction was never in any of 576 lenses examined in a group of the cheapest purchasable sun glasses, of an amount as large as the minimum visual resolution of the eye. Furthermore, an examination was made of the visual acuity of a group of 40 persons, through lenses whose optical (telescopic) resolving power varied from equal to ground-and-polished lenses, to the worst that could be selected out of the 576 lenses examined. This showed no differences in visual resolving power for any degree of optical resolution found among these lenses. It is therefore concluded that the method of preparation of the lenses, by any of the three types of manufacture described above, has no effect on the wearer of detriment due to optical quality. This does not mean that "bad" sun glass lenses cannot be made, but that modern methods of manufacture cannot be expected to produce "bad" lenses.

A method of manufacture, once quite common, was to blow the molten glass into a bubble of about two feet diameter, from which lenses were cut and directly mounted in sun glass frames. These lenses, called *mi-coquilles*, are frequently of considerable prism power, and are liable to spherical and cylindrical aberration. However, and fortunately, this method is no longer of economical advantage.

These conclusions concerning method of manufacture are of considerable public importance, since the cost of the three methods is greatly different. Whereas drawn glass, cut and then dropped, called "*coquilles*" in the trade, sell for less than \$3.60 per gross, plate glass sun glass lenses may cost this much per dozen pairs, and ground and polished lenses may cost this much per pair. It is easy to understand, with this much price differential, that the method of drawing the glass, then cutting and bending the lenses, produces the greatest bulk of civilian sun glasses.

III. Conclusions.

A. Civilian Sun Glasses.

Accordingly, we are able to prepare a sort of "prescription" for civilian sun glasses. This prescription will not have to be greatly modified for general issue in military procurement. We would suggest, for civilian consumption, that the color of the glass be anything that people are willing to buy, since the effect of the partial color constancy of the retina under various colored lenses indicates that nearly any color will be "essentially" non-selective unless it is obviously color-distorting to a degree that would make it an unpopular item. We would recommend that civilian sun glasses be darker than those at present offered on the market, that is, that the sun glasses be near 10%, and not over 25% transmission. Since the drawn and bent glass does not contain large optical errors, and certainly does not reduce visual acuity, we should recommend that there be no prejudice against cheap sun glasses. Since there is little possibility that glass which is colored would transmit very much infra-red or ultra-violet light, and since the effect of these wavelengths was generally admitted to be not harmful, by this Committee, we would not specify infra-red or ultra-violet absorption in civilian sun glasses.

III. Conclusions.

B. Military Sun Glasses.

Military procurement might be guided somewhat by these researches, at least to the extent that such procurement should be directed towards protection against subsequent loss of retinal sensitivity after exposure to sun light, and should therefore be directed toward transmission from 7 or 8% to about 15%. Since military pro-

curement should concern itself with the availability and expense of materials, there should be no prejudice against drawn and dropped lenses, unless some generalized specification for limits of dioptric power are included. In such case, it is believed that a limit of $1/4$ diopter would be harmless, that a limit of $3/16$ would not be uneconomical, and that a limit of $1/8$ th diopter would not be impossible for the industry to meet.

Certainly, the further procurement of polarizing sun glasses should be abandoned, as should the procurement of any plastic material, until some surface treatment has been developed that will render the plastic at least reasonably scratch-resistant.

As far as aviation sun glasses are concerned, we would recommend that such sun glasses be from 12% to 18% transmission, as at present specified (An-G-22-a), that they be as nearly neutral (non-selective) as possible, that they be made of ground and polished glass blanks, since these can be heat-treated to be very resistant to breakage. If special purpose glasses, as for landing on snow, searching for tracer-fire, or similar specific problems, are to be used, they should be frankly developed to satisfy the needs of the problem, recognizing that under the conditions of the problem, the non-selectivity of the glass is no longer of paramount importance.

IV. Availability of Glass.

No discussion of sun glasses, especially from a military point of view, would be complete without careful consideration of the availability of the lenses to be used. In the case of glass lenses it must be recognized that certain unalterable factors limit the availability of what might be considered the most desirable type of lens. Glass is colored by the addition of certain few metallic oxides to the molten mixture of sodium carbonate and sodium silicate which make up the bulk of the material. In the case of greenish glass, iron oxide is used; to produce a purplish and nearly neutral glass, nickel is used. In the preparation of sun glass lenses, combinations of several such oxides are used. To produce a neutral glass, one first adds nickel, but one must now attempt to remove some of the remaining blue and violet transmission, which can be accomplished with cerium. This results in a straw-colored glass, which is not desirable nor attractive. Therefore, copper may be added, not enough to produce the blue-green color of copper alone, but only enough to produce a less yellowish combination. But this is no longer neutral, so a little cobalt must be added, turning the glass into a nice gray at high transmissions (low thicknesses) but rendering the glass purple again at higher thicknesses. Since the colorants are so limited, and not nearly infinite, as in the case of organic dyes usable in plastic, the final glass cannot be expected to be truly non-selective, in the sense that the carbon-suspension Wratten gelatine filters are neutral.

Other effects hamper the coloring of glass. For example, if it is decided that the smoother and less complicated spectral curve of simple iron glass is more desirable than the ragged spectral trace of such a mixture as described above, difficulty is met immediately in any attempt to render the glass sufficiently dark at the thicknesses used for sun glass lenses. The addition of enough iron to produce the desired density will so increase the infra-red absorption of the glass that large batches can not be heated into the center. Such a glass is therefore stringy, and totally useless for the purpose of sun glasses. It can thus be seen that the glasses which have thus far been produced represent a very considerable effort on the part of the glass makers, and suggestions that darker glasses than those already

available for market should be prepared, are not met with general enthusiasm.

It has already been stated that coquilles of drawn and bent glass are the cheapest form of sun glasses, and that they do not adversely affect visual acuity. These glasses are drawn in the form of continuous sheet, from a tank of molten glass containing 30 tons or more. As fast as the glass is drawn from one end, much as one might draw candy from a dish of melted sugar, the raw materials are added to the other end of the tank. The process, once started, is continuous, and enough glass must be drawn from a single such melting to prepare millions of pairs of sun glasses, before the tank, still containing 30 tons, is allowed to cool, and the process stopped. The glass so produced can be extremely inexpensive, but this will be true only if the volume consumed is large enough to warrant the original tank preparation. Consequently, in procuring sun glasses, procurement must be either directed toward glass already available, or must be undertaken in very large units of production, that is, in units in the neighborhood of half million pairs. Even then, some considerable latitude must be allowed in the specification of the glass, when new glass is to be developed.

When a glass is chosen, which has already been produced, the batch of glass is already in the form of drawn sheet, and the lenses can be prepared from glasses already finished. In such case, specifications are hardly necessary, since the lenses will be all alike in the glass composition.

The industry producing ground and polished plate, to be cut and bent, cannot produce a great volume of lenses, even with several competing companies. In this process, smaller amounts of glass are made at a time. However, the production is relatively slow, and the expense is very much greater.

With regard to lenses ground and polished to curve, the labor of preparation becomes more expensive than the preparation of the raw glass, and in this case, it is possible to prepare very small batches of glass, and to discard such batches as do not meet specification. In this case, moreover, since every batch will vary, in spite of all care to the contrary, it is necessary to prepare quite rigid specifications if successive procurements of a few thousand sun glasses at a time are expected to resemble each other. In the case of prescription corrective sun glasses, and in the case of aviation sun glasses, both of which are ground and polished from small bits of roughly cast glass a few millimeters thick, and two inches in diameter, the expense of preparation alone is so great that the cost of the glass becomes an almost negligible part of the cost of the finished lens.

V. Summary

In summary, we might say, resulting from the researches carried out during and since the war, that sun glasses are necessary for all military personnel, at whatever station. Three types of such sun glasses should be procured. Type I, sun glasses for aviators, type II, sun glasses for other personnel, and type III, sun glasses for use by persons wearing prescription lenses.

Type I, for aviators, should be made of as nearly non-selective neutral gray glass as can be obtained, ground and polished to curve, and heat treated to reduce breakage. Specifications for these glasses could be simplified from the AN-G-22-a form, by deleting the present Daylight Duplication Index, which is objectionable because of arduous arithmetic labor it imposes. A suggestion is embodied in the Index of Color Constancy, or visual matching to a limit of Munsell Chroma (/1) can be used. The glass should transmit from 12 to 18% at 2.0 mms. (Such glass would

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transmit from 16 to 21% at 1.8 mms., and from 9 to 15% at 2.2 mms.)

Type II. General issue sun glasses, for non-aviation personnel, should transmit from 8 to 15%, and need not be colorless. The presently available colors known to the trade as "essentially neutral" are not objectionable. The glass can be used in the form of coquilles made from drawn and bent glass for the sake of the great economy involved. There is no objection to bent plate glass, nor to the expensive ground and polished glass, provided that the limit of refractive error be held below $3/16$ or perhaps $1/8$ th diopter. Actually, errors as high as $1/4$ diopter are not considered harmful.

Type III. Sun glasses for persons wearing prescription corrective lenses. These can be "fit-over" or "clip-on" type, and as such can be prepared from coquilles made of drawn and bent glass. However, because of the awkwardness of such contraptions, plus their inherently small field of protection, it is recommended that corrective lenses be made of tinted glass, transmitting from 8 to 15% in the center of the lens.

Polarizing sun glasses are not recommended.

DISCUSSION:

Comdr. Farnsworth commented that the color constancy obtained when the field is completely covered by a selective material may not occur with ordinary sun-glasses with which the peripheral field is not covered by the selective material. This might mean that the color constancy observed by Dr. Peckham might not permit one to conclude that selectivity of sunglasses will not interfere with color perception under normal conditions.

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MEETING OF THE WORKING GROUP ON SUNGLASSES

November 14, 1949

Those present were the following:

Dr. Stanley S. Ballard
Col. Victor A. Byrnes
Dr. Alphonse Chapanis
Dr. Forrest L. Dimmick
Lt. Comdr. Dean Farnsworth
Dr. David M. Freeman
Dr. Henry A. Imus —
Dr. Deane B. Judd
Major M. E. Kay
Col. Austin Lowrey, Jr.
Dr. Donald G. Marquis
Dr. John L. Matthews
Dr. Kenneth N. Ogle
Dr. R. H. Peckham
Lt. George W. Rand
Dr. James T. Ray
Dr. H. W. Rose
Dr. William Rowland
Dr. Ingeborg Schmidt
Dr. Richard G. Scobee
Dr. Louise L. Sloan
Capt. John T. Smith, USN
Dr. F. E. Washer

Dr. Imus presented the request received from the Bureau of Medicine and Surgery concerning sunglasses for use by Naval flying personnel. He asked the Sub-committee to discuss the relative value of various neutral and selective sunglasses.

Commander Farnsworth recommended that sunglasses should be essentially neutral in order to avoid distortion of color perception.

Dr. Peckham emphasized the difficulty of specification of neutral and the difficulty of manufacturing non-selective sunglass materials. He referred again to his research results indicating the apparent lack of difference in color perception for the degree of selectivity possessed by ordinary commercial sunglasses.

Dr. Judd pointed out that a gray glass can have color distortions if it is dichroic. He emphasized the need for separating the specification for all-purpose sunglasses from that of special sunglasses. A dichroic glass might, for example, prove valuable as a contrast enhancing glass for special visibility purposes.

Dr. Matthews pointed out that any sunglass differing from neutral will have exaggerated effects upon the color perception of color anomalous persons.

Dr. Rose mentioned that any green lens will produce impairment of the perception of red signal lights.

Colonel Byrnes questioned the desirability of as low a transmission as 10% for sunglasses for flying personnel. He expressed his opinion that such a glass is

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too dark for ordinary purposes. He commented that if sunglasses are issued to pilots they will use them for driving their automobiles with possible resultant danger due to the low transmission.

Dr. Rose commented that in his opinion, 10% or less transmission is satisfactory for pilots or for use at the beach, but stated that truck drivers should have a higher transmission sunglass than 10%.

Dr. Peckham reminded the Wording Group that the 10% transmission level was selected partially on the basis of the degree of protection of dark adaptation offered by the glass. He stated his belief that otherwise comfort is the only factor in the determination of a desirable sunglass transmission.

The Working Group agreed upon the following recommendations:

The Navy neutral sunglass N-4 is satisfactory for the use of flying personnel. Colored sunglasses (green, amber, rose-smoke, Calobar) are less satisfactory for general use. It is to be noted that sunglasses with special spectral selectivity may have special uses. Uniform or gradient density coatings are acceptable for special purposes, but have no general value. The sunglass E8314 made by Bausch and Lomb which is claimed to be satisfactory neutral and yet to provide contrast enhancement, is not considered satisfactory either as a neutral or as a contrast enhancing sunglass. It is considered that no further testing is needed at present to determine satisfactory sunglasses for general flying use.

Dr. Imus presented the questions directed to the Working Group by the Quartermaster General of the Army. The Quartermaster General wanted opinions on the following questions:

- (1) "Do polarizing lenses offer any advantages to the wearer of sunglasses over other types of tinted lenses?"
- (2) "Does the use of polarizing lenses eliminate glare at higher levels of light transmission as compared with tinted lenses?"
- (3) "Does the use of polarizing lenses contribute to the comfort of the wearer in any way differently from tinted lenses?"

In addition, the Quartermaster General wished the recommendations of the Working Group concerning the issuance of clip-on sunglasses for military personnel requiring refractive curve lenses. After some discussion, the Working Group accepted the following recommendations:

Polarizing lenses do not offer sufficient advantages over non-polarizing lenses to warrant general issue, but may be desirable for specialized uses involving polarized light from snow or water.

When it is impossible to supply tinted ground lenses, clip-on sunglasses are considered acceptable. It is considered that the clip-on sunglass is not a completely satisfactory solution to the problem because the peripheral visual field is not protected by clip-on sunglasses. General issue sunglasses should be made of glass of suitable quality until a more satisfactory neutral gray, hard-surface plastic is available. Power dis-

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tortion should not exceed $1/8$ diopter; visual transmission shall be 8 to 8/15%; the glass shall be essentially non-selective in transmission.

RESEARCH IN VISION
Related to Disorientation
LCDR. Henry A. Imus, MSC, USNR (Inactive)
Captain Ashton Graybiel, MC, USN

U. S. School of Aviation Medicine and Research
Naval Air Station
Pensacola, Florida

Report to
Armed Forces-NRC Vision Committee

14 November 1949

Introduction:

Research in visual illusions related to flying was initiated early in 1944 because of a series of unusual aircraft accidents which occurred at the Naval Air Training Bases at Pensacola. Investigations of these accidents revealed what seemed to be a common factor - confusion or disorientation of the pilot just prior to the crash.

In order to determine the kind and frequency of visual illusions in flight, a survey and controlled interview experiment was established. Vinacke¹ interviewed 77 Naval aviators and concluded that various types of disorientation may occur in any type of aircraft at any altitude and may follow almost any type of maneuver. However, this vertigo, as he calls it, is most likely to occur under extremely hazardous conditions, such as under adverse weather and visibility conditions and at night. Sensory illusions predominate (69%). The remaining proportion is attributable to psychological and emotional factors or to the establishment of conflicting clues. His results called attention to the need for further experimentation on both sensory and psychological factors, and for an educational approach to the problem for the purpose of eliminating some of the mystery and fear involved.

On the basis of a suggestion of Dr. Walter R. Miles that autokinesis might be involved, experiments² were conducted to study this phenomenon. Both laboratory experiments and tests in flight were conducted under controlled conditions in order to determine the characteristics, incidence, temporal factors, and magnitude of the phenomenon.

These studies showed that the autokinetic illusion is a phenomenon commonly experienced by normal persons under conditions which favor its occurrence. The apparent motion of a single light observed in the dark, either in the laboratory or in the air, is difficult to distinguish from real movement and is not subject to voluntary control. The object appears to drift, now in one direction and then in another, for more than half of the time. However, certain factors tend to decrease or eliminate the phenomenon. They are: factors which improve the spatial localization of objects, such as increasing the number of lights in a plane; rapid relative motion of the target, such as when another plane flies on a crossing course; the temporary shifting of attention from a given target for more than ten seconds; and the dependence upon flight instruments for proper orientation.

Another approach to the problem was made in the study of nystagmic eyemovements of the subject and the apparent motion that follow violent rotation. Considerable study has been made of the variability of vestibular nystagmus, its magnitude, dura-

tion, phases, and other aspects by Barany, Dodge, Dusser de Barenne and de Kleijn, Holsopple and others. The possibility that some of these illusory effects might be produced during standard maneuvers of aircraft during flight necessitated further experimentation³.

These experiments were conducted with the Barany chair, the rotating Link Trainer and on the Human Centrifuge. The principal variables introduced were the illumination, both general and that of the target, the direction and intensity of the stimulus, and the position of the head of the subject.

The results show that, in a lighted room, relatively strong vestibular stimulation is required before visual illusory effects are noted. In the dark, however, the threshold for apparent motion is as small as 0.2 - 0.3 degrees of rotary acceleration per second per second. Measurements in the dark are complicated by the auto-kinetic illusion when the target is a single light. This complication is removed by using a three-dimensional target, consisting of a box with illuminated borders.

When relatively strong stimulation is used, as, for example, the sudden cessation of rotation following twenty revolutions of the subject at 25 rpm, a series of illusory effects are obtained. The target moves rapidly in a direction opposite to the recent rotation for 30-40 seconds, followed by a second apparent motion in the opposite direction of nearly the same duration. In some instances a third apparent motion in the same direction as the first may be observed for a few seconds. By inducing an after image of a vertical filament in the eyes it can be demonstrated that these apparent motions are due to nystagmic eye movements. Following cessation of rotation, the after image always seems to move in a direction opposite to that of the image of the illuminated box.

Further laboratory experiments⁴ were undertaken to investigate the relationship between apparent displacement and apparent motion in the oculogyral illusion. The results for twelve subjects show that the target is observed as displaced, 50° - 50°, and always in the direction of the apparent motion. From the literature, one is led to conclude that there are large individual differences in the amount and duration of apparent displacement and that this response persists briefly after the motion has ceased. Again decline in the duration of motion or of displacement, either from trial to trial or day to day, does not occur.

Experiments in the positioning of the head of the subject during rotation show that the direction of the apparent motion takes place in the plane of the particular semicircular canal which is stimulated. This indicates the relatively simple reflex character of the phenomenon, because there is no evidence of any conscious attempt to interpret the movements as occurring in relation to the plane of the earth.

In general, this group of experiments show that the apparent motion of a visual target, which is induced by vestibular stimulation and which has been named the oculogyral illusion, provides an excellent indicator for the study of the sensitivity of the sensory receptors involved, the reflexly produced nystagmus and other psychophysiological phenomena related to the manipulation of aircraft in space.

A further complication was added to the experiment with the Link Trainer by introducing real motion in the visual target.⁵ This resulted in an apparent displacement of the target in addition to the apparent motion.

During the experiments in the human centrifuge, another type of visual illusion was discovered. This is called the "oculo-gravic" illusion, because it is induced by accelerative forces measured in terms of gravitational units. A review of the literature showed that Brewer, in 1875, had distinguished between the otolith organs, which respond to the position of the head in space (gravitational effect), and the semicircular canals, which respond to rotation of the head in one of the three principal plans (change in velocity). The "oculo-gravic" illusion provided still another means of studying orientation. Using an infinity target for visual fixation, and with the head held firmly in the primary position while the subject faces the center of the centrifuge, changes in the centrifugal forces produce marked changes in the apparent position of the visual target.⁶ As the centrifuge is accelerated slowly in the dark the image of a horizontal line in the infinity target, which is mounted directly in front of the subject's eyes, appears to rise until it is estimated to be 45° above the horizon. When the rate of revolution of the centrifuge becomes constant, the target appears to remain fixed for that particular speed of revolution. Meanwhile, the subject, who is strapped erect in a chair, feels himself gradually tilted backwards until he feels as though he were lying on his back and looking up at the target. When the power is cut off, and the centrifuge coasts to a stop, the subject reports that the target gradually returns to its true position, and he soon feels that he is sitting erect. The apparent position of the image throughout the experiment seems to be in line with the resultant of the gravitational and centrifugal forces acting upon the otolith organ.

Another series of experiments⁷ was undertaken in the human centrifuge in order to determine the quantitative relationship obtaining between the resultant of centrifugal and gravitational forces acting upon the subject and his perception of the visual vertical when no visual frame of reference was present. Using the psychophysical method of average error, the subjects were required to adjust a luminous collimated line until to them it appeared to be vertical. Adjustments were made under stationary conditions, and during eight different angular velocities ranging from 4 rpm to 11 rpm. It was found that the visual vertical varies directly with the angle of the resultant force. Individual differences occur in both constant and variable errors, but the combined data of these experiments, based upon 480 adjustments, indicate a relatively accurate perception of the visual vertical (Mean, Constant Error = -0.38° , $\sigma = 1.30^{\circ}$). Individual differences increase with increasing angular velocity. It is concluded from these experiments that Mach's hypothesis, which states that subjects adjust the visual vertical in accordance with the resultant of centrifugal and gravitational forces, is supported. Furthermore, these experiments indicate that, without a visual frame of reference, visual orientation is dependent primarily upon postural factors.

The experiments in the human centrifuge led to further empirical tests in flight. The experiments described in three reports⁸ were conducted in the rear cockpit of an SNJ-6 aircraft, using a fixed collimated "star" as the visual target. The observer recorded his observations on a wire recorder. The results show that illusions of motion and displacement of the visual target may occur during all degrees of bank from 10° to 60° and always occurred during banks of 40° and above. Although there are marked individual differences between subjects, there is a direct relation between the degree of bank and the amount of apparent motion and displacement observed. When two methods of executing a banking maneuver are compared, no significant differences in the illusory phenomena are observed. These two methods are described as follows: (1) executing a turn with constant power setting and changing the angle of attack of the wing to maintain proper altitude; (2) executing a turn by holding the angle of attack constant and increasing power to maintain altitude. In the first case, there is a definite change in the magnitude and direc-

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tion of the accelerature forces acting upon the subject. In the second case, there is a change in the magnitude of the forces without a change in direction. It is apparent that repeated maneuvers do not lessen the effects; therefore, it is safe to assume that habituation does not occur.

In order to verify this assumption experimentally, three subjects were rotated in the Link Trainer for 14 days for an average of approximately 20 successive runs per day. No evidence of habituation appeared in the data. This report⁹ states that the oculogyral illusion can be expected to occur at night in pilots of aircraft when accelerations above threshold are present. This lack of habituation appears to be true in spite of extensive flight experience of the pilot.

SUMMARY

Unusual aircraft accidents led to a long series of experiments on visual illusions which were thought to affect pilots in operating aircraft at night or under adverse conditions of visibility and weather.

A survey of experienced aviators revealed that such illusions were relatively frequent in occurrence.

Experiments on the autokinetic illusion indicated that this type of illusion could occur in night flying and could be reduced by increasing the number of formation lights on the planes, and by instructing pilots to shift their gaze.

Experiments in a Barany chair, a rotating Link Trainer and the Human Centrifuge indicated that acceleration and deceleration forces produce illusions of motion and displacement of visual targets. Other experiments on the human centrifuge show that gravitational forces cause displacement of visual targets and illusions of changes in bodily position. These experiments were confirmed by flights "under the hood" in a Naval training aircraft.

CONCLUSION

This series of experiments, which have been conducted over a period of five years, has contributed much to our knowledge of orientation in space, and has emphasized the importance of properly indoctrinating cadets and pilots concerning visual and other illusions which may increase the hazards of flying. For example, these experiments have shown, without equivocation, that pilots flying at night or through fog, experience the same bodily sensations, whether they are in a climbing turn or in a diving turn. The training of pilots to rely upon instruments instead of their bodily sensations, no matter how overpowering the latter may be, is of critical importance. When pilots understand the causes of these illusions, much of the mystery and fear involved is removed.

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School of Aviation Medicine and Research

U. S. NAVAL AIR STATION

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A NEW ASPECT OF THE FUSIONAL PROCESSES IN
BINOCULAR SINGLE VISION*

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Nepi

We need a measure of the strength of the compulsion to fusion as an indication of the efficiency of the binocular visual mechanism and its ability to cope with muscle imbalances. The only measures available are the so-called prism vergences or fusional amplitudes. Prism vergences are, at least in part, measures of the fusion ability, since the fusion reflex cannot be separated from the convergence mechanisms. However, it is questionable whether fusion power alone is being measured. In prism vergence tests, probably three variables are involved: (1) The degree of the forced convergence (or divergence), (2) the strength of the fusion compulsion reflex, and (3) the degree to which the otherwise normal accommodative-convergence reflex is altered or embarrassed. The stimulus to accommodation (the target distance) is constant throughout the test.

It is the increasing stress in the convergence-accommodation reflex together with that of the musculo-mechanical processes which is pitted against the compulsion for fusion as the forced convergence or divergence is increased. Diplopia occurs either when that stress is so great as to overcome the reflex innervation to maintain single binocular vision or when the mechanical limits of the oculomotor muscles are reached.

Experimental evidence indicates that in spite of the compulsion to register the dioptric images of the two eyes as near as possible on corresponding retinal points, there occurs an actual small deviation of the eyes and a corresponding slipping of the cortical images, although fusion is still maintained. Identical target patterns observed on the two sides of the stereoscope will appear under normal conditions single, and then the images of these patterns are said to be "fused." Dissimilar (and fusible) details centered on each of the same two patterns will under certain conditions appear decentered, that is, will appear displaced relative to each other, in spite of the fusion of the images of the identical patterns. This displacement occurs especially when the observer is heterophoric, or when the convergence and its normal corresponding stimulus for accommodation are altered. This phenomenon has been designated a fixation disparity because the evidence indicates that the retinal images of the point of fixation may be actually disparate.

While this phenomenon may be a common observation among those who use the stereoscope or haploscope, it was Lau who first described and correctly interpreted it while performing experiments on a different problem. Under the designation of "retinal slip," Ames and Gliddon reported experiments with the haploscope in which they were able to show that the direction of the displacement of the small discs within the larger ones was generally the same as the direction of the phoria of the observer. The apparent magnitude of the displacement cannot be predicted, however, by the degree of the phoria.

The phenomenon rests on the well-known fact that disparate images in the two eyes can be fused, if that disparity is not too great, that is, if they fall within the so-called Panum fusional areas. The phenomenon of fixation disparity, which can

* A condensation of the paper "Fixation Disparity and the Fusional Processes in Binocular Single Vision" Amer. J. Ophth. 32:1069-1087 (Aug.) 1949.

be demonstrated to exist in a majority of subjects, implies that the cortical images arising from the two eyes are actually displaced a small amount with respect to each other. The angle of fixation disparity is a measure of the degree to which the images have slipped, in the same sense that Panum's area, although measured as a retinal dimension, pertains to a cortical area within which disparate images are fused. The processes involved in the compulsion for fusion normally strive to keep the images from the two eyes as nearly as possible on corresponding points. Fixation disparity as a measure of the displacement of the cortical images will depend on the strength of the innervations and stresses of heterophoria, the strength of the fusion processes themselves, and the amount and complexity of the detail in the binocular field of view.

The purpose here is to report systematic measurements of the fixation disparity as influenced by a number of factors. It was thought that the fixation disparity might be an estimate, if not an actual measure, either of the strength of the fusional reflex or conversely of the strength of those forces--innervational or/and anatomic--which tend toward an incorrect pointing of the eyes, while the images of the two eyes are actually fused.

On an aluminum-coated screen, set up 2.5 meters from a subject's eyes, patterns and special test configurations were projected by lanterns (fig. 1). The subject observed the screen through a phorometer, to which had been attached a pair of Polaroid plates before the two eyes with the planes of polarization at right angles to each other. The target for fusion stimuli consisted of Snellen charts projected by lantern, the total field subtending an angular size of about 20 degrees. A small central area of a given size could be blanked out at the center of the target and thus appear black to the subject. The size found convenient is a square that subtends a visual angle of about 1.5 degrees to the subject. With this center no stimuli for fusion are present within the foveal regions of the two eyes, but details for fusion exist everywhere outside this area.

The test configuration was projected on the blank square at the center of the screen by a second lantern into which a special slide arrangement had been built. The test details consisted of a horizontal bright line, and a pair of opposing (vernierlike) short vertical bright lines (arrows). The lights from the arrows were polarized so that one arrow would be seen by one eye and the other by the second eye. The upper arrow was fixed (stationary) but the lower could be displaced horizontally by means of a special mechanical arrangement in the lantern, which was operated by a screw and knob on the outside. The displacement of the two arrows was read by the experimenter from an accurate dial indicator on the lantern, to an estimated 0.2 minute of arc (angle subtended to the subject), which is well within the maximal sensitivity found. By means of a shutter arrangement, the lower arrow could be occluded or flashed onto the screen at the will of the operator. The long horizontal line prevented fusion of the arrows and possibly reduced any tendency for a vertical deviation.

The phorometer is adjusted to the subject's head so that the eyes are centered. The phoria was estimated by using the Maddox rod, a spot of light being projected on the screen in a room totally dark. The target (with the 1.5-degree central square) and the test arrows are then projected on the screen. With the Polaroid plates removed (both eyes observing the target), a determination of the dial reading is made for which the arrows appear in alignment, as well as of the least perceptible displacement (a measure of the precision) that can be detected. The operator instructs the subject to look at the upper arrow, and then he flashes the lower arrow for a fraction of a second, after which he asks the subject whether that arrow

appeared to the right of, to the left of, or was centered with the upper arrow. Between flashes the lower arrow is displaced to a new position. By the method of limits the average midpoint and precision are determined. The zero of the dial indicator is then adjusted to that reading from which the subject reports that the arrows are in alignment. This procedure eliminates the constant personal and instrumental errors.

The Polaroid plates are raised and the operator checks that the right eye sees only the upper arrow, and that ghost images are absent. By means of the shutter the lower line is then exposed for short intervals of about 0.25 second, and the subject is asked, as above, to judge whether this arrow was right or left of the upper arrow, or even with it. By adjusting the amount of displacement, and obtaining the patient's response, the average position and the limits can be found within which he reports that the two arrows appear aligned. The actual displacement of the arrows is expressed by the angle, in minutes of arc, subtended at the eyes of the subject.

The experiment then proceeds by the determination of the fixation disparity for different values of prism power introduced by rotary prisms before the patient's eyes. For most subjects the prism power was placed alternately base-out and base-in; the base-out in 4^Δ steps and the base-in in 2^Δ steps. The alternation of base-out and base-in procedure was found necessary to avoid cumulative effects. Thus, while following to some degree the procedure in the test for prism vergences, one measures here any deviation of the eyes from their positions for exact fusion that may occur during the procedure. The change in the actual deviation during the test provides new data for studying the fusional processes as the eyes are subjected to changes in convergence by prisms and changes in the stimulus to accommodation by lenses.

Typical results are shown in the accompanying graphs. In these, the difference in the angle of convergence caused by the prisms compared to that for the 2.5-meter observation distance, measured in meter angles, is plotted on the abscissa, positive for convergence and negative for divergence. The measured fixation disparity in minutes of arc is plotted on the ordinate, being taken as positive if the deviation of the eyes is convergent and negative if divergent. Inspection of these graphs shows that points representing the data for each subject describe a sigmoid-like curve, the shape of which is different for different subjects. Four fairly definite types of curves are distinguishable. Typical graphs illustrating two of these groups are shown in Figure 2 and in Figure 3.

Consider for discussion the data for W. A. P. in Figure 2. This subject is nearly emmetropic, with a visual acuity of 6/6 in both eyes, but shows an esophoria of 6 to 8 prism diopters for the 2.5-meter visual distance. With no prisms before the eyes (or the rotary prisms set for zero power), the two arrows had to be displaced 6.6 minutes of arc for them to appear aligned. This finding shows that the eyes were actually over-converged by 6.6 minutes of arc, which is in the same direction as the phoria. When prisms are placed base-out before the two eyes, a convergence is necessary if fusion is to be obtained. This convergence of the eyes is made, but if the convergence-accommodation reflex is active, this convergence will be resisted because the accommodation cannot change appreciably without blurring the vision. This resistance to the forced convergence would be manifested as an exophoria or a decreased esophoria if the fusion were not present, or as a change in the fixation disparity in the direction of a divergence. Such a reaction is demonstrated in this subject. When prisms are placed base-in before the eyes, a divergence of the eyes is forced, and the reverse behavior in the fixation disparity is to be expected. Since the limits of prism vergences base-in at this fixation distance are not large, the fixation disparity increases rapidly because the point of diplopia is quickly reached.

Considerable difference between subjects is found in the limiting prism power for forced convergence caused by prisms base-out. On approaching that point, fusion may become too unsteady for reliable measurements and diplopia may occur intermittently. In several subjects the data could not be obtained to the point of diplopia because of blurring, micropsia, and the ocular discomfort associated with the sustained convergence.

One of the striking aspects of these data is the smallness of the quantities being measured and the precision within which they are obtainable. If the visual acuity is high and the muscle balance is fairly normal, it is usual to find the limits within which the two arrows appear in alignment of the order of 1 minute of arc, and often less. The precision decreases with lowered visual acuity, and decreases considerably as the degree of the forced convergence or divergence becomes large, because the relative positions of images seem more unstable and liable to change. The small normal involuntary eye movements that are always present and which appear to increase with the stress accounted for occasional spurious responses. As the prism vergence approached the point of diplopia, fusion of the images became more uncertain, and here greater discrepancies in the repeated data were found.

Data of the nature of those described in these experiments cannot fail to vary somewhat from day to day, depending on rather intangible factors associated with the individual. For some subjects, the precision of measurements seemed to vary from one day to the next for no obvious reason, although fatigue, previous excessive use of the eyes, and even disinterest may have been specific factors. However, in spite of this variation, the general curve obtained for a given subject, after the lapse of several days, agreed remarkably well with that previously obtained. This must not be taken to imply that no changes are found, for frequently the second curve may be displaced from that taken first by a small degree, in the same sense that the phoria will change from day to day. The particular technique used in exposing the arrow also generally had no significant effect on the curve obtained.

That the curves of observers fall into one of four rather distinct groups is one of the striking aspects of this study. Subjects with curves intermediate between these are also found however. In the first group (fig. 2) the fixation disparity increases with the forced convergence (or divergence) of the eyes, and in the middle range the increase is almost directly proportional to the prism power. For these subjects, as the prism power is increased, the cortical images from the two eyes increasingly "slip" and the fusion of these images becomes increasingly less exact, until finally a confusion and then a diplopia occurs. Although the rate of change in the deviation with prism power suggests itself as a measure of the strength of the fusion reflex (the higher, the poorer the fusion), this is not borne out.

In the second group (fig. 3) the eyes maintain more or less the same degree of fusion, over wide ranges of forced convergence, as evidenced by the fact that the fixation disparity changes little between the limits near which sudden increases are found. The fusion of the two images for these subjects appears to be tightly held in spite of the increased prism power. Even for high degrees of forced convergence certain of the subjects showed only a small increase in the disparity, until the point was reached where abrupt changes might be expected.

This second type of curve is not unexpected, for it might be anticipated that the fusional processes would hold the images tightly together during the entire prism vergence test, until a sudden giving way would occur at the limits with resultant diplopia. However, one would expect the fixation disparity to be zero be-

tween these limits. The anomalous factor shown in these data is that more or less constant actual fixation disparity is maintained between those limits. The precaution taken at the beginning of the measurements to determine the "zero" for each observer precludes the possibility that this displacement is a constant personal or instrumental error. The direction of this disparity in the level portion of the curve appears generally to be in the direction of the phoria.

The third type, which occurs less frequently, is similar to and in some cases almost indistinguishable from the second, except in the manner in which the data approaches one of the diplopia points. In general these approach the constant value much more gradually, but on reaching that, they remain constant until diplopia or extreme blurring occurs. In most cases the vision becomes very blurred and suppression may set in, yet the fixation disparity insofar as it can be measured does not change at the confused end point.

A fourth type of curve is also found occasionally in which the fixation disparity actually changes with forced convergence only in a very narrow interval, but outside this interval, the curve for both further increased convergence or divergence levels off at nearly constant values. The subjects of this group usually appear by even ordinary tests to have poorly developed binocular coordination, especially for near vision.

In the first group, the deviation increases with the degree of forced convergence, while in the second, the fixation disparity remains nearly constant with the degree of forced convergence or divergence, except near the limits of the fusional amplitudes. From one point of view these data indicate that in the first type, fusion is more loosely held and the cortical images are more liable to slipping than in the second type, in which the fusion is more tightly held until the limits of fusional amplitudes are reached.

The existence of a more or less constant fixation disparity in the second type is difficult to account for. In a tightly held fusion, the second type of curve would be expected, but with the greater part of the curve coinciding with the abscissal axis, that is, with the fixation disparity zero. Only near the limits of the fusional amplitudes would there be a sudden change in the curve. The measurements of the fixation disparity as the fusion details are confined more and more peripherally constitute a crucial experiment. Otherwise, it might be argued that the constant deviation in the second group might be the result of an adapted change in the sensory subjective direction, in the same sense of an anomalous correspondence, developed by a constant fixation disparity under the influence of a neuromuscular tension.

The better explanation for these results is that the stress set up in the accommodative-convergence relationship produced by the prisms differs greatly with different individuals. Here two groups could be differentiated. In the first, a real stress is caused by the prisms, in an effort to resist the forced convergence. In addition to these stresses, there must be those manifested by the phoria. In the second group, the disproportion between the accommodation and the convergence due to the prisms introduces little or no additional stress at all; there is practically no resistance to the prisms, as though the accommodation and convergence relationship was exceedingly elastic, until the degree of convergence or divergence becomes great. Thus, in spite of the forced convergence caused by the prisms, only those stresses manifested by the phoria remain as the sole source for the ocular deviation. Hence, the fixation disparity would tend to remain constant. It would tend to be constant for a given pattern of fusion detail and only

secondarily to be influenced by a change in phoria with convergence.

If the details for fusion are limited more and more to the peripheral visual field, the fixation disparity curves change markedly, although again this is different in the several groups of subjects. By increasing the size of the blanked-out square in the projected fusion pattern on the screen, in the center of which the vernier arrows are seen, the images which can be fused are restricted more to the periphery of the retinas. For a given convergence the fixation disparity increases rapidly as the size of the blanked-out area increases. Since Panum's areas in the periphery are many times larger than those in central vision, such increased disparity is possible while still maintaining fusion. The precision of the data decreased also. The data were obtained for the series of target sizes at each prism setting; hence the results found were not cumulative effects of the forced vergences. The fixation disparity increases as the fusion is pushed into the periphery.

There would be reason for expecting that the fusion in the face of opposing stresses would be more difficult when the retinal images are blurred, because all contours on which fusion will depend would be less distinct. However, the fixation disparity curve obtained also does not change appreciably when the images of both eyes are blurred by plus ophthalmic spherical lenses at distant vision or with occluder (special etchedlike) glasses. However, if the image of only one eye is blurred, the fixation disparity does change with prism vergence, which indicates a less exact fusion.

Because the change in fixation disparity with forced convergence or divergence is probably associated with the convergence-accommodation reflex, similar changes might be expected when the stimulus to accommodation was also changed, as, for example, when spherical ophthalmic lenses are placed before the eyes. The procedure was to obtain data for the curves for the fixation disparity with forced changes in the convergence while spherical lenses are placed before the two eyes, for both distant and near vision.

For distant vision, three sets of data were obtained: with the usual or with no refractive correction, and with supplemental lenses of +1.0D. sph. and -1.0D. sph. before both eyes. In each case the added sphere caused a displacement of the curves. As would be expected, the fixation disparity changes in the divergent direction with plus spheres, and in the convergent direction with minus spheres, which is in the direction that the phoria would also tend to change. The addition of the plus spheres in both cases blurred the vision somewhat, but not sufficiently to prevent data being taken, although the sensitivity was reduced.

For the near-vision (29 cma) tests new instrumentation was necessary. A light box with a transparency plate in front was used instead of the projector lanterns and screen. The features are essentially the same as those for the distant-vision apparatus, and no further description is necessary. If the subject had adequate accommodation, supplemental lenses of +2.0D. sph. and -2.0D. sph. were used, while if not, as in beginning presbyopia, supplemental lenses of +2.0D. sph. and +4.0D. sph. were used.

It is a special interest to derive from these curves the various combinations of spheres and meter angles of convergence (prism power) each of which results in a given fixation disparity, especially a zero disparity, for then the cortical images would be exactly superimposed. The comparative influence of prisms and lenses on fixation disparity and the convergence-accommodative relationship can be

found. For two subjects 0.6 and 0.8 meter angle of convergence (3 to 4 prism diopters) has the equivalent effect on fixation disparity of 1 diopter of lens power before the two eyes.

At this time it is not possible to attach special significance or functional importance to the "zero" disparity line, although certainly this could be taken as the condition of no muscular imbalance and perfect fusion, and as such it would be desirable. As far as the spherical lenses are concerned, it appears that when the subject wears the proper refractive correction the fixation disparity is small, if not actually zero.

A fixation disparity can be measured in most subjects who show a heterophoria, regardless of the type of fusion detail used in the target. By and large, the direction of the fixation disparity is the same as that of the heterophoria, although apparently not correlated quantitatively with it, probably because the phoria is a phenomenon of the disassociated eyes. Fixation disparity a priori need not always be associated with a phoria. The stresses of dynamic muscular balance active during actual fusion may be the result not only of mechanical and tonic neuromuscular effects but also of functional innervations, all of which would not necessarily be present when the eyes are disassociated. Occasionally, the initial fixation disparity is found in the direction opposite to the phoria, and generally this occurs in the case of a small esophoria which nevertheless exhibits a divergent deviation.

The purpose of presenting this material here is to point out a new measurement that gives us additional information about the fusion and the accommodation-convergence functions in binocular vision. It is still too early to know what the clinical value of these measurements is. The fact that differences in curve patterns exist between individuals points to further experimentation to correlate these with other visual behavior.

DISCUSSION:

Dr. Scobee emphasized the possible usefulness of the measurement of fixation disparity for clinical application. He stated his understanding that Dr. Ogle believes fixation disparity to be an adjustment made by the patient to his phoria. If this is so, it will be possible to determine the clinical significance of a phoria depending upon the existence of "loose" or "tight" fusion.

Dr. Ogle commented that more research was needed before such a clinical application could be made. He stated that in general the phoria did agree with the intersection point of the disparity curves with the X axis. However, Dr. Ogle reported that he has found an increasing number of people whose phoria does not agree with the intersection point. It is these people in whom phoria is unstable.

Dr. Peckham asked whether Dr. Ogle had made any measurements of eye movements.

Dr. Ogle reported that the magnitude of the displacement was only a few minutes of arc so that eye movement measurements would not be feasible.

Dr. Peckham then asked whether a modification of the technique could be employed in order to eliminate binocular imbalance from aviation cadets.

Dr. Ogle stated that one would like to eliminate fixation disparity, but that one can not prescribe 10-12 diopters of prism in order to do so.

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Dr. Grether asked whether a patient ever starts vergence in the wrong direction when a prism is suddenly placed before his eye.

Dr. Ogle reported that vergence never starts in the wrong direction, unless the patient simply does not understand instructions.

Dr. Grether commented that his reason for asking concerned the reflex nature of the fusional process.

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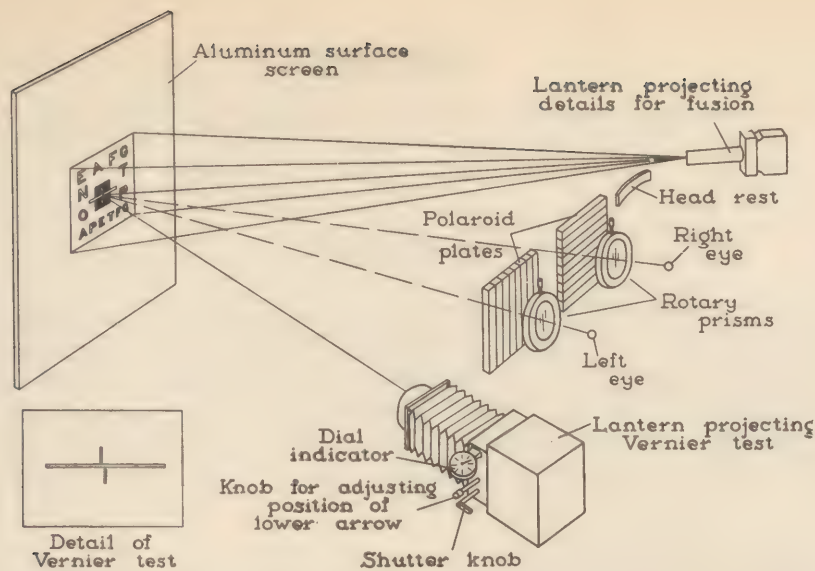


Fig. 1 Perspective drawing of the instrumentation used to measure fixation disparity.

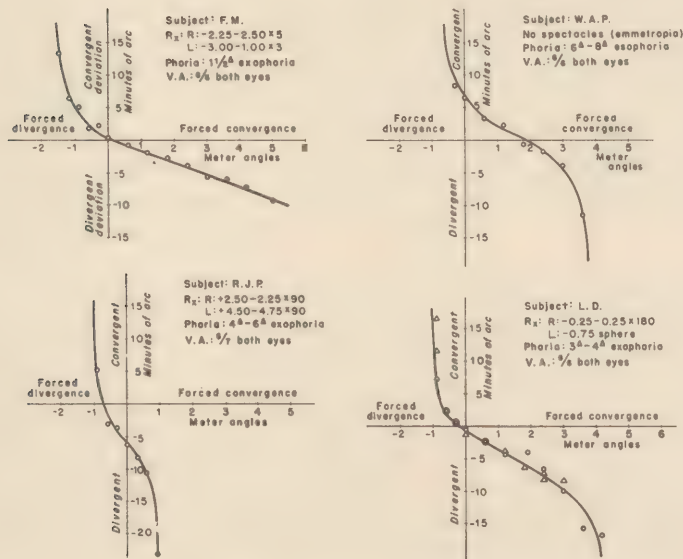


Fig. 2 Typical data of subjects for whom the fixation disparity changes with forced convergence and divergence caused by the prisms before the eyes.

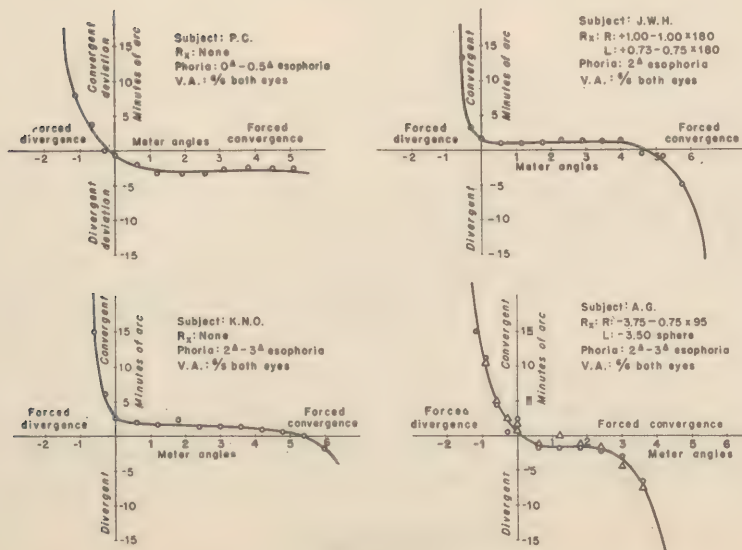


Fig. 3 Typical data of subjects for whom the fixation disparity changes only slightly with forced convergence except at the limits of the fusional amplitudes.

THE EFFECT OF TRAINING ON COLOR VISION DEFECTS

by

A. Chapanis

The effectiveness of training on color vision defects has been discussed at Vision Committee meetings on several occasions. Thus, at the second meeting of the Army-Navy-OSRD Vision Committee (18 May 1944) Lt. Dean Farnsworth stated as a "Known fact of color anomaly" that "Color anomaly cannot be cured or significantly changed by training. 'Treatments' are usually followed by viewing the A. O. Plates; this results in simple learning and the eventual inclusion of more color anomalies in the Services."

This subject came up again before the sixth meeting of the Army-Navy-OSRD Vision Committee (12 October 1944) in the form of a request from Captain J. H. Korb that the Committee consider the method advocated by Dvorine (3) for the corrective training of color deficient individuals. Captain Korb proposed "that some disinterested group might attempt to validate the claim that this method can train color blind individuals to be able to pass service color vision tests and possibly cure color blindness." The discussion which followed this proposal showed quite clearly that committee members were not in sympathy with it. It was generally agreed that the Dvorine claims had little merit and that they were not worth a validation study. It was also agreed that the American Medical Association Council on Physical Therapy, whose function it is to evaluate cures, should be requested to consider the Dvorine method as a cure.

On 15 July 1947, Lt. Comdr. Dean Farnsworth prepared a report and extensive bibliography on the subject (5). His report was essentially a summary of the opinions of visual scientists concerning the possibilities of corrective training. The opinions cited were those of Dr. Deane B. Judd, Dr. Glenn A. Fry, Lt. Comdr. Dean Farnsworth, and the members of the Inter-Society Color Council Subcommittee on Problem No. 11, Color Blindness Studies, who transmitted their unanimous reply through the secretary, Miss Dorothy Nickerson. The opinions of nearly every authority on color vision in America are represented here. All these individuals were unanimous in their convictions that the basic sensory capacities of color deficient individuals cannot be improved by medicine, training, or other therapy. They also agreed that practice and coaching will undoubtedly enable a color deficient person to pass, or to show an improved score on, an imperfect test, but that this improvement does not constitute evidence of rehabilitation in the true sense of the word.

Commander Farnsworth's report was transmitted to the American Committee on Optics and Visual Physiology and at the twenty-first meeting of the Armed Forces--NRC Vision Committee (27 May 1948) Dr. Conrad Berens announced that the report had been accepted by the Committee on Optics and its component societies--the Section on Ophthalmology of the American Medical Association, the American Academy of Ophthalmology and Otolaryngology, and the American Ophthalmological Society. Dr. Berens also stated that publicity for Farnsworth's report had been authorized in the form of articles in Sight-Saving Review and Hygeia, and an editorial in the Journal of the American Medical Association.

All of these steps were highly necessary and worthwhile, but it must be recognized that they represent largely an argument by appeal to authority. We would all undoubtedly agree that the subject is not worth an extensive, or indeed even a minor, research program. Most of us would also agree with Judd, Fry, Farns-

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worth and others that congenital color deficiency cannot, at the present stage of our knowledge, be improved by therapy or training. Nonetheless, there is some value in accumulating genuine data to support our views--if for no other reason, then simply for their propaganda value.

There are a few--but only a few--reliable studies we can turn to for data on the effectiveness of training. Bridgman and Hofstetter (1), for example, have shown quite conclusively that it is possible for color deficient men to improve their scores on the American Optical Company test through practice. They pointed out, however, that this improvement occurred only if the men (a) were told or could figure out when they made mistakes, and (b) were allowed to examine the plates. If the men were tested with test A, "trained" on materials that did not include test A, and then were reexamined with test A after the training period, there was no measurable improvement. Essentially the same sort of data have been reported by Gallagher et al. (6).

These are still not completely conclusive data because it is possible to argue that neither Bridgman and Hofstetter nor Gallagher et al. used the correct kind of training in the first place. For this reason, I was delighted when I had an opportunity to examine recently two men who had been trained by optometrists during the war years. One of these men was trained by an optometrist whose name he could not recall. He did recall, however, that he had been trained by looking at red and green lights for extended periods of time. (This is a procedure recommended by Lepper (7) and Smith (8).) He also recalled that his training cost him \$165, or just about \$10 an hour.

The second man was a Baltimorean who specifically remembered having been trained by Dvorine. In fact, it appears quite certain that this man is "J. R. -- Case IX" described in an article by Dvorine (4). J. R. underwent a series of training exercises with Dvorine (at about \$10 an hour) during December 1944 and January 1945, and at the conclusion of this training was able to pass the A. O. test at a naval recruiting center.

At the time I saw them, both men were quite obviously and unmistakably color deficient as measured by the Ishihara, American Optical Company, Boström-Kugelberg, and my own experimental tests. Although this is about what we might have expected, it seemed to me that these findings were worth reporting to the group. The full report may be found in reference (2). We may safely conclude that two men, after being subjected to the approved routine by optometrists who "had the secret," were still color deficient a few years later.

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PRELIMINARY REPORT OF TEST METHODS FOR DETERMINING RESOLUTION SCALE
AND CONTRAST REQUIREMENTS FOR THE DETECTION AND
RECOGNITION OF OBJECTS ON AERIAL PHOTOGRAPHS

John T. Watson
Boston University

The main purpose in putting this topic on the agenda of the committee is not so much to show any results as to invite criticism of the methods which are being used. Our Optical Research Laboratory personnel is not as familiar with the subtle methods necessary in psycho-physical testing as are most of the people in this audience. For these reasons, before the tests have progressed very far, we are submitting this preliminary report before a group of people who can point out possible oversights.

I am sorry Dr. Macdonald couldn't be here to tell you in his own words about this project and its significance. In his absence, I shall try to give you a complete picture of the work.

The study originated after a statement by an officer in the Department of Air Intelligence, Washington, D. C., who said it was difficult to tell from the resolution in lines/mm what ground detail a lens would resolve. He wished to know what objects could be recognized with an aerial camera. When pushed farther he said that the observer would like to be able to discern detail about the size of a two-foot cube. Though he would not elaborate on the statement, this requirement was on record as one of the first reasonably definite statements about necessary camera quality to come from an intelligence officer.

This almost looks like a step backwards since the resolving power chart in lines/mm had only recently abolished the former methods of inspecting prints for detail. However, a program was set up at the Boston University Optical Research Laboratory to determine how two foot object resolution correlated with resolving power in lines/mm.

After a few attempts to apply Rayleigh contrast criteria, contrast gradients, and grain structure, in conjunction with lines/mm the experimental approach appeared to be more solid. Some preliminary aerial tests were made, showing that a laboratory set up was first in order to achieve controlled conditions and separate the variables.

A laboratory set up was made to simulate aerial scales of 1:5000, 1:10,000, 1:20,000 for two foot objects. In the laboratory, a 20mm f/1.4 biotar, stopped to f/5.6, was used to photograph objects of 1/4-inch dimensions. Objects, and backgrounds, of three different diffuse reflectivities were used, giving nine different combinations of object to background contrast. The reflectivities were 5%, 13%, 40% --neutral gray. The important contrast is thought to be that on the film itself. Therefore, object to background contrasts are measured on the film.

In order to completely bracket the phrase "discern two foot cubes", tests were provided for detection of objects as well as recognition of the difference between objects. For the detection tests, objects all of one kind are used. For recognition as a first approach cubes and cylinders of the same cross sectional area are used together.

To make scoring easier, the test objects are arranged on a square neutral back-

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Ground. This square area is divided into 25 sections, 5 rows of 5 squares each, numbered down the sides and lettered across the top and bottom. This makes it rather easy for an observer to record the location of the object he saw -- 1A, 2C, etc. Provision is made in the set up for different resolution levels by throwing the image slightly out of focus with ophthalmic lenses. Five different resolution levels ranging from about 4 lines/mm to 60 or 70 lines/mm on Super-XX film are thus obtained. To simulate different shadow conditions the lighting of the set up can be varied to give no shadows or shadow lengths up to 4 times the object height. Provision for the image motion, common to most aerial photographs is provided in the camera -- a Fairchild Oscillo Record Camera with moving film. The regular objective of course, is replaced by the 20mm Biotar.

Provision will also eventually be made for stereoscopic viewing of the set up.

The work we have been doing is aimed at reaching liminal values of detection and recognition. Toward achieving this goal we have been trying to approximate a forced discrimination procedure. In our case it works like this:

For Detection

Ten objects are placed in the 25 possible locations at random, and photographed for one condition. The observers are told that there are ten objects in the target area and that they must make ten space choices or more if they see more objects. The guessing factor is then eliminated by calculation from the number wrong.

For Recognition twelve cylinders and thirteen cubes are placed randomly in the twenty-five locations. The students are told that there are 13 cubes and to find the 13 most probable places in which they lie. Again the percentage score is corrected by taking into account the number wrong.

The negatives are being analyzed for resolution, object count, and discrimination by our three girl analysts using binocular microscopes. However, for getting more statistical data than can be had from our three regular analysts, we have set up a projection system using a Spencer Universal Projector and an f/2 Sonnar lens. The projection distance is 31 feet. Seven student observers sit at $15\frac{1}{2}$ feet from the screen. In conjunction with a 2-inch projection lens this gives them an effective angular magnification of the negative of 10 times. For object count, we find the 10X magnification about right. For object differentiation, higher magnification about 20X with the students closer to the screen, is necessary.

These values are given for the 1:10,000 scale. For other scales, we vary the magnification to keep the retinal image approximately the same size. Thus, the effect of grain structure is changed by the scale. Object to background contrast is measured in the projection setup by a photocell scanning across the screen in conjunction with an Esterline Angus Recorder.

The square target area subtends about 5° total angle at the students' eyes. The objects subtend about $8'$ of arc when they are in focus. A subdued surround lighting extends the total illuminated screen to about 20° . The brightness of the screen varies from about 0.7 foot lambert to about 2.5 foot lamberts depending on the target background. At this level, with a surround of about 0.5 foot lambert, the viewing seems very comfortable over 20 minute periods of time.

Here are some slides, enlargements of the original negatives which can be projected on the screen.

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First, for object count here are some 10X prints of the original 1:10,000 scale negatives of 5% objects on a 5% background with a 1X shadow. For the first, Figure 1, with a resolution of about 9 lines/mm, an object count of some 50% was achieved. The second, Figure 2, is the slide at about 16 lines/mm. Here a 100% count was achieved.

The next four slides, Figures 3, 4, 5, and 6, are of one differentiation arrangement, scale 1:5000, with different resolutions, 4.5 l/mm, 10 l/mm, 18 l/mm, and 63 l/mm.

Here we have 40% objects on a 40% background, which can be differentiated from one another only by the shadows.

The final slide, Figure 7, shows only some very preliminary results of object count and object differentiation of 40% objects on a 13% background at 1:10000 scale. These slides are presented only as preliminary data and are not useful as yet to draw more than a simple conclusion. As might be expected, the pure count of objects reaches 100% accuracy at a resolution value of less than one tenth that necessary to differentiate between the objects. However, it seems safe to say, even from these meager data, that there is little likelihood of distinguishing 2-foot cubes on the ground from the same size cylinders, monocularly at a scale of 1:10000 on Super XX film, with any of the standard aerial reconnaissance cameras.

This work is continuing presently, with the hope of learning more about the various factors in the quality of photographs which enable observers to interpret the detail.

Discussion:

Dr. Blackwell suggested that the psychophysical procedure used in Mr. Watson's study might be improved by restricting the discrimination the observer had to make to that of the presence of a single object from a number of possible spatial positions. As Mr. Watson reported it, the subject would be required to report in which squares he detected objects. This procedure would probably be more effected by expectations than a procedure in which a single positive occurrence was used. For example, the subject would undoubtedly expect that adjacent squares would not contain targets, whereas by chance, this would happen a certain percentage of the time. This kind of expectation would be minimized by presenting the subject, for example, with four squares in one of which a target would always be presented. The subject would be required to discriminate in which square the one target was presented on each presentation.

Mr. Watson agreed to try this change in procedure and to forward his comments to Dr. Blackwell.



Figure 1

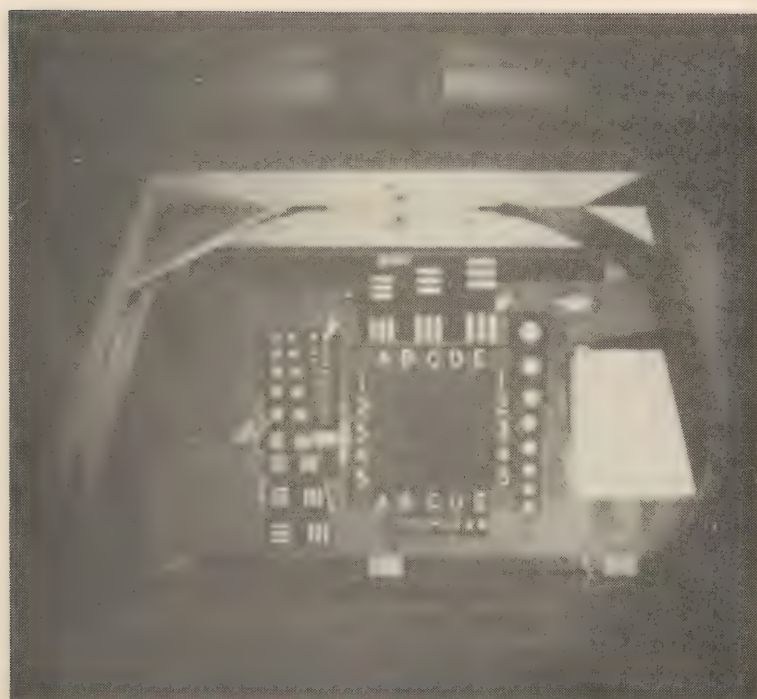


Figure 2

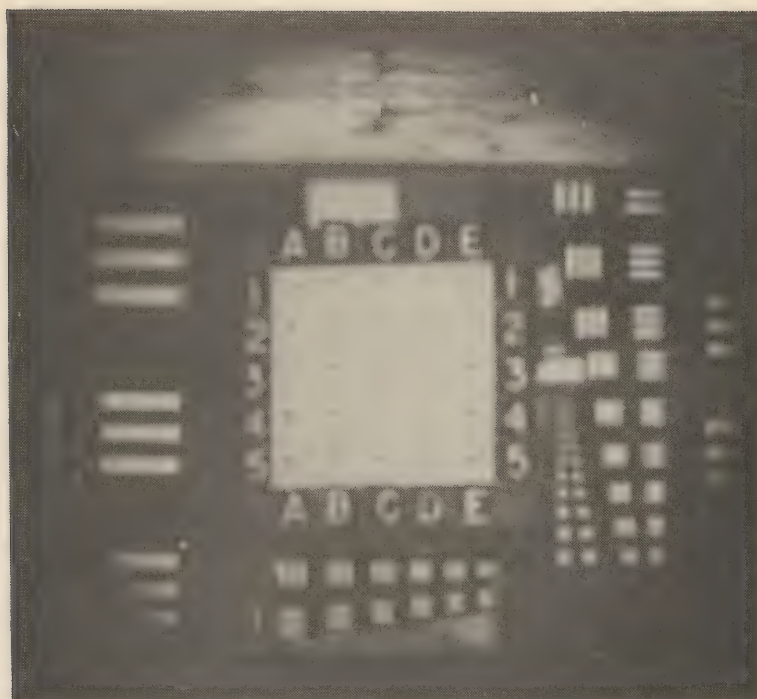


Figure 3

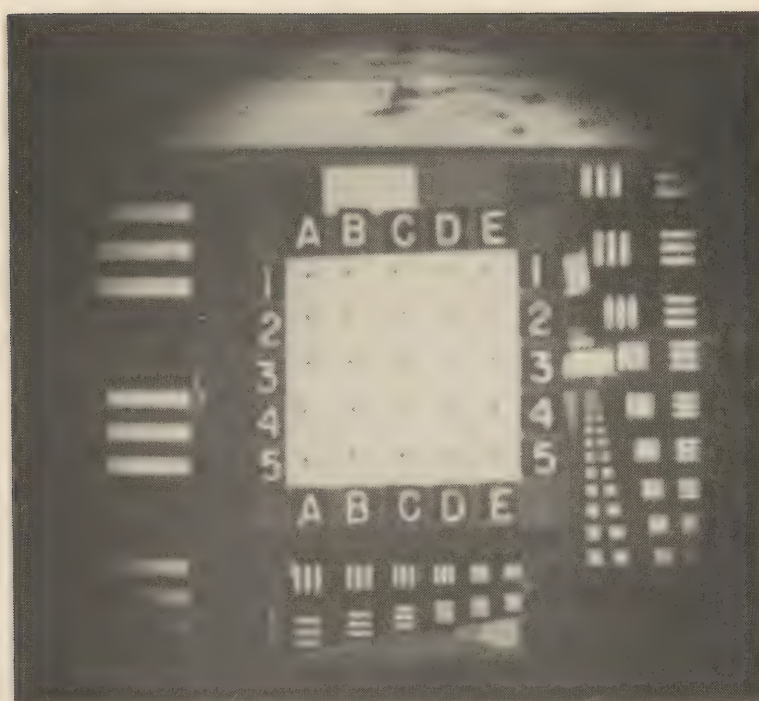


Figure 4

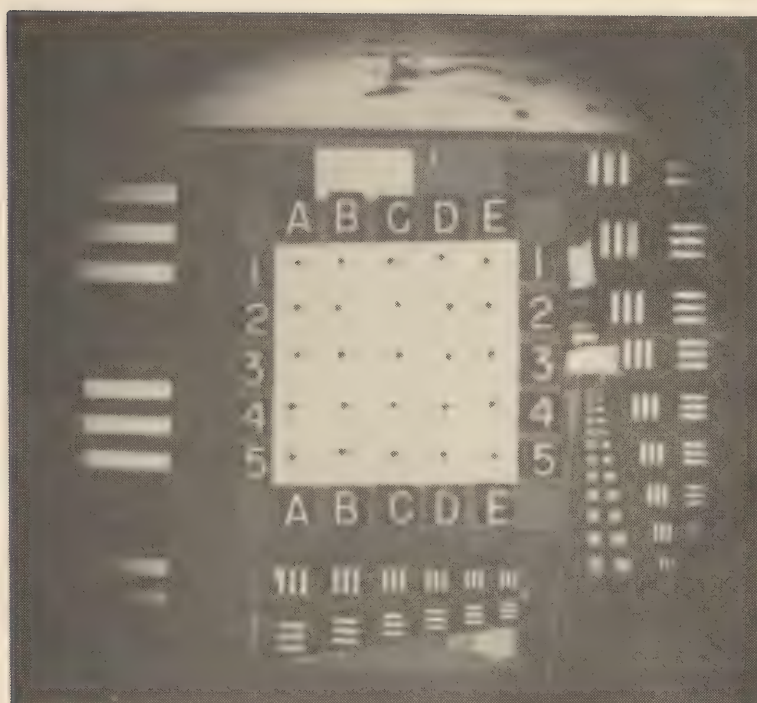


Figure 5

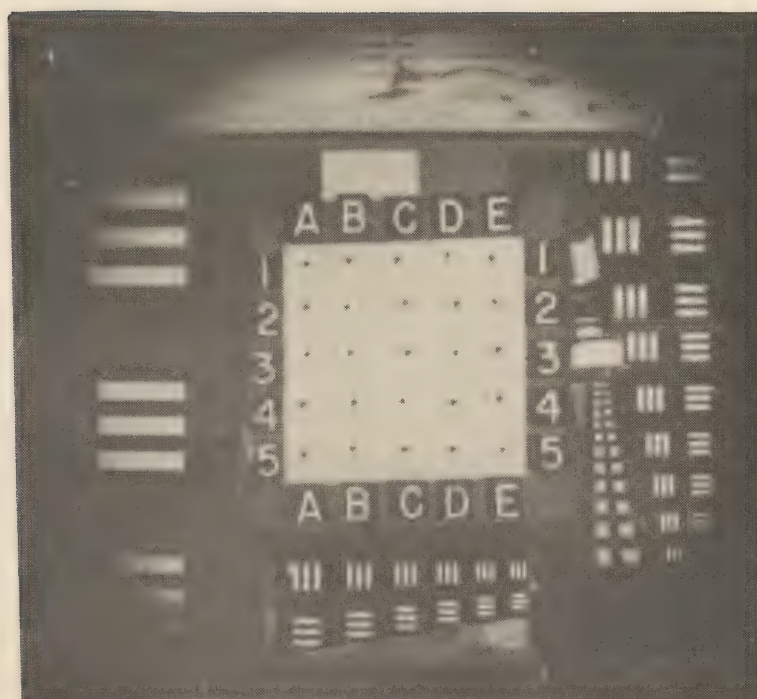


Figure 6

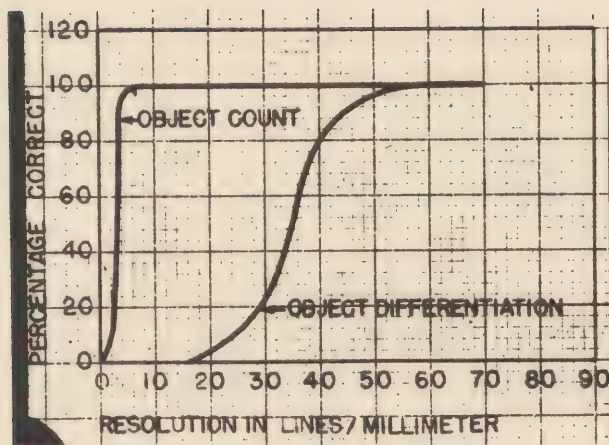


Figure 7

THE METHODOLOGY OF EQUATING
SNELLEN LETTERSDean Farnsworth
U.S. Submarine Base

1.

Back in April 1945, we recognized "four variables in testing visual acuity" and set up a Sub-committee on Visual Standards whose initial job was the codification of testing procedure. Three of the objectives, standard illumination, control of the physical condition of the men and regular procedure for examination are now incorporated in the Manual of the Bureau of Medicine and Surgery of the Navy. Good strategy required that the fourth objective, an acceptable test chart, should be by-passed at that time: "Fourth, until test objects of minimum separable resolution have been tried out thoroughly in the field, it is reasonable to suggest that properly printed Snellen charts whose letters are equated in difficulty should be issued to all stations....".

2.

Reasons for Considering Letter Targets

I do not defend letters; I am merely resigned to them. The objections to letters as test objects are too well known to require restatement here. There is no doubt as to the validity of the objections. Yet physicians continue to choose techniques on the basis of personal choice or intuition or for reasons which are not susceptible to experimental analysis. Exactly 40 years ago the Eleventh International Ophthalmological Congress adopted the Landolt Ring as the international test object but few ophthalmologists possess such a chart. They will not wear their own prescription.

It appears that letter charts are popular because:

- (a) they are "liked better" by the examinee, (Ref. (1), p. 135)
- (b) they are more interesting to the doctor⁽²⁾
- (c) everybody is used to them (and people have a touching faith in what they are used to)
- (d) they can be instructive to the oculist who is attempting the best optical correction for reading, particularly with relation to astigmatism. (This is somewhat beside the point in selecting charts for determining unaided acuity)
- (e) letter charts are believed to be comparable to the reading problems ordinarily encountered in everyday life.^(3, p. 57) (This apparent face validity is largely spurious when applied to Snellen type letters)

To the above we can add a valid and practical reason for preferring letter charts to some geometric forms: they can be produced more carelessly and can be subjected to more office abuse with less effect on the scores.

Because of this aura of acceptability and because of the relative ease of production it was thought worthwhile to continue the experiments begun in 1945 at Randolph Field and at New London and we are reporting certain of the problems and solutions because they appear to be generally applicable to the construction of visual tests. There is an added reason for reporting our experiences: the almost complete lack of agreement between the results of previous workers in letter analysis requires explanations - which the present study has somewhat provided.

It is noted that we are leaving all considerations of chart arrangement to a later study. This includes size and gradients of visual angle, layout, spacing,

mutual effects of adjacent items, influence of position within lines and the intangibles of literal influences.

3.

Reasons for Selecting Snellen Letters

Of the three available letter types, sans-serif or single stroke, old style print as in Jaeger Letters, and the block letters of the Snellen type, we chose the Snellen to work on because:

- (1) it is 'easy to manipulate their design while retaining the basic principles of construction related to resolution.
- (2) they are least susceptible to training.
- (3) each item can be given the same visual weight.

Fortunately, the construction of the Snellen letter is based upon the same principles of resolution as is the checkerboard test item.

The comparison in Figure 1 will make this clear. It is evident that whatever system of retinal gradients are involved in the resolution of a block letter (so long as it adheres to Snellen's principles) is the same as for a checkerboard or grid except that the retinal pattern is less regular for a letter.

This similarity is substantiated in the AGO study in which it was found that the factor loadings for "resolution" of all checkerboard type tests and Snellen letter-type tests were high and substantially identical. We are therefore justified in crediting Snellen type letters with the ability to measure retinal resolution. Their other vagaries are of peculiarly annoying sorts. Each letter is a separate kind of test item and at times seems to have a complex personality which it is our purpose to reduce to a norm insofar as is possible. Further, there are variations between the letters in order of difficulty from individual to individual but, by the use of a substantial number of observers it is possible to obtain an average equality of difficulty for a population.

4.

Construction of Targets

We tried to retain as many as possible of the rules for the construction of the Snellen letters.

- (1) Letters should extend to the four sides of the 5 x 5 square.
- (2) The stroke width should be $1/5$ th the size of the square. This permits us to vary the spacing between strokes and to vary the length of the serifs and to vary the radius of curve of the round letters as means to equalization in difficulty.
- (3) We add one rule - the items should be of equal "visual weight." We have created the phrase "visual weight" to describe the apparent size or blackness of the blurred image which we have found to be a factor of learning independent of recognition by resolution. Weight is calculated as a proportion of black area to the 25-square background. In the series of letters shown in Figure 2 this ratio ranges from $\frac{13.8}{25}$ squares for the U to $\frac{16.4}{25}$ squares for the Z - a difference which is reflected in their respective ease of recognition.

5.

Problems

First, the field problem. The influences of spacing and surrounding letters were removed by presenting the letters individually and with a reasonably large sur-

round, uniformly lighted to 12 foot Lamberts. Problems of interrelationships were deferred for later study.

Second, the problem of foreknowledge or familiarity. Differences were found between tests run with successively smaller target subtenses as against those run in reverse. It was necessary to make a choice, and the decision was based upon these practical considerations: (1) that most of the tests a man will receive in his lifetime will be with charts with which he is familiar, (2) that most charts are presented with the larger letters first, which constitutes foreknowledge for even one test series, and (3) that when obscure blurs are first presented to the observer, he will adopt mental "sets" which will persist past the stages when free recognition should occur, and thus prejudice the data at larger subtense. Therefore, in spite of the fact that retest reliability was found to be lower for decreasing subtense, experimental runs were designed to give responses which began with 100% correct and decreased to 0%.

Third, the problem of reliability. The results of Jackson⁽⁴⁾, Elschmig and Gnad⁽⁵⁾, and Coates⁽⁶⁾ are in decided disagreement between themselves and with later work. Previous to this year we have tested six sets of letters; split half correlations on those results have shown unreliability as great as that found in the literature. This suggests that individual variability of response to letters is greater than has been estimated and that insufficient numbers of observers have been used in previous tests.

Fourth, the "end-point" problem. What criterion of difficulty will be used? Lythgoe⁽⁷⁾ has shown the higher dependability to be expected from the traditional 50-50 limen, but the use of other criteria in practice required that the data be so taken and analyzed as to reveal differences if they exist.

6.

Results

1. The Effect of Foreknowledge. Fifty subjects were tested with the order of targets which gave increasing visual angle (0→100% correct); fifty subjects at decreasing subtense (100→0% correct). It was found that:

a. Correlations of reliability were higher at each distance by the method of increasing subtense (without foreknowledge).

b. The proportion of correctly called responses is higher by the method of decreasing subtense (with foreknowledge). At each distance, considered separately, there was not a significant difference between the two methods at the 5% level. However, the probability that the decreasing subtense method will yield higher proportions at all distances is significantly different from a chance variation.

2. The Number of Subjects Required for Reliability. The insufficiency of previous studies is attested by this data. One hundred men were tested and retested on series in which each letter was presented twice at each of five subtenses. Analysis of the data taken by this plan showed an average reliability of .90 for 100 observers, .65 for 50 observers.

3. The Treatment of the Data. Most previous studies have grouped data from observers according to the angles subtended by the test letters, a method which obscures actual differences between items. This results in diminution of apparent differences between letters. For example, the study by Jackson⁽⁴⁾ ascribed a .71 to 1.00 ratio between the extreme Snellen letters "L" and "B", whereas Coates⁽⁶⁾, the only investigator to use our treatment, reported a visual acuity ratio of .37

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to 1.00 for the same letters. By analyzing data grouped according to the visual acuity of the observers and by using the classical 50-50 limen, we obtain ratios of .21 to .80 from the eighth revision (whose items are much closer in equality than any previous series), which permits treatment of higher reliability of the differences.

4. Reliability of Differences. The central problem in the evaluation of letter tests is to find a method which would establish the reliability of the differences in the data. For this analysis, we used the t test of the proportion of correctly called responses.

$$t = \frac{p_1 - p_2}{\sqrt{\frac{p_1 q_1}{N_1} + \frac{p_2 q_2}{N_2}}}$$

An analysis of variance of the data collected this year attested to the reliability of the letters (No. 7). Therefore, in our last two runs (No. 7 and No. 8), in spite of individual differences of observers, it is possible to tell when the variance between the letters was found to be significantly greater than the variance within the letters.

The vertical lines in Figure 2 divide the letters of the 8th revision into four groups which were found to be significantly different in difficulty at the 50% limen of recognition. They indicate the groups in which revision promises to be fruitful.

5. Selection of "End-points." Study of early revisions showed regular tendencies of letters to "drift" within the group from easy to difficult according to their subtense.

For instance, where average recognition was 20%, the letter K ranked third hardest, and, as the visual angle increased, it ranked progressively easier until at the 90% average recognition point for all letters it was the one most often recognized. Other letters shifted their rank position to the opposite direction, and those which were most often recognized at a distance become least often recognizable at near.

This caused us to ask at what resolvable visual angle would letter charts be most often used? For what conditions of use are we equating these letters? It appears that there are two:

- (1) The traditional psychological limen which will probably continue to be used in laboratory work, that is, the 50-50 point of recognition.
- (2) Since clinicians are addicted to the less reliable method of "all the letters right in a line" or "all the letters but one right in a line" (current Navy practice), it appears that charts made for clinical use should be examined at the 90%-to-100% right level.

Data was then analyzed at these two limens in later revisions. If the two sets of values had continued to be irreconcilable, then two types of charts would have to be anticipated for the two uses. However, an interesting development occurred. Reference to Figure 2 shows a remarkable correlation in the last revision. The 8 easiest letters at the 50% level, for example, maintain the same ranked order at the 90-100% level. This suggests that the differences in rank order at various subtenses may be a function of inequality and will continue to diminish with improvement in equalization.

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The letters at the top of Figure 2 are reproductions of the actual test items under discussion. Revisions will be dictated by the above considerations, which may be summarized as follows:

1. Redesign within the "checkerboard" principle of construction.
2. Equate the "visual weight" of items.
3. Secure test and retest data from not less than 100 observers.
4. Treat data grouped according to visual acuity of observers.
5. Analyze at 50% and at 90% limens of recognition.
6. Continue revision as long as the variance between letters remains significantly greater than variance within letters.

Tests in this experiment were run under the direction of Mr. Ira Schwartz; the experimental plan and statistical analysis were made by Miss Doris Newman, Head of the Statistical Facility of Medical Research Laboratory.

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DISCUSSION:

Dr. Chapanis commented that it is a well known fact that the mean and standard deviation of psychophysical curves do not necessarily correlate. He pointed out that this was the basis for the shift in relative difficulty of the letters when the absolute difficulty was changed.

Commander Farnsworth agreed that the effect was well known, but emphasized that it had not been generally recognized with reference to the problem of difficulty of visual acuity test observations.

Dr. Sloan asked whether any of the Farnsworth subjects possessed uncorrected refractive errors.

Commander Farnsworth replied that his subjects were "run of the mill" Naval personnel whose visual acuity ranges, in general, between the limits 15/20 and 20/15.

Dr. Sloan commented upon the large individual differences discovered in relative difficulty of various visual acuity letters. She remarked that equating letters in difficulty for the average difficulty does not give results which are useful for the testing of individuals. She reported an experiment in which artificial

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refractive errors were introduced by ophthalmic lenses, the result being a change in the relative difficulty of various test letters. She suggested the desirability of using the same letters in every line so that individual differences in the difficulty of letters would not affect the relative difficulty of various acuity test lines. Dr. Sloan remarked that Snellen was aware of the fact that the "visual weight" of various letters must be made the same.

Dr. Peckham asked in what way the equated letters are "better"? He commented that in the measurement of refractive error the decision of the ophthalmologist is not often made on the basis of how many letters can be read, but instead on the basis of subjective sharpness. In this way, the practicing ophthalmologist does not utilize the letter chart in the same way in which Commander Farnsworth is using it.

Dr. Uhlaner commented that he hoped the final report of Commander Farnsworth's work would include the standard error of difficulty of each of the letters so that individual differences could be evaluated. Dr. Uhlaner also commented on Commander Farnsworth's comparison of Snellen letters to checkerboards. He pointed out that there is no necessity for an a priori evaluation of similarity between these two tests of visual acuity because of the data obtained in the AGO study. These data indicated that there was no great factorial similarity between the two tests.

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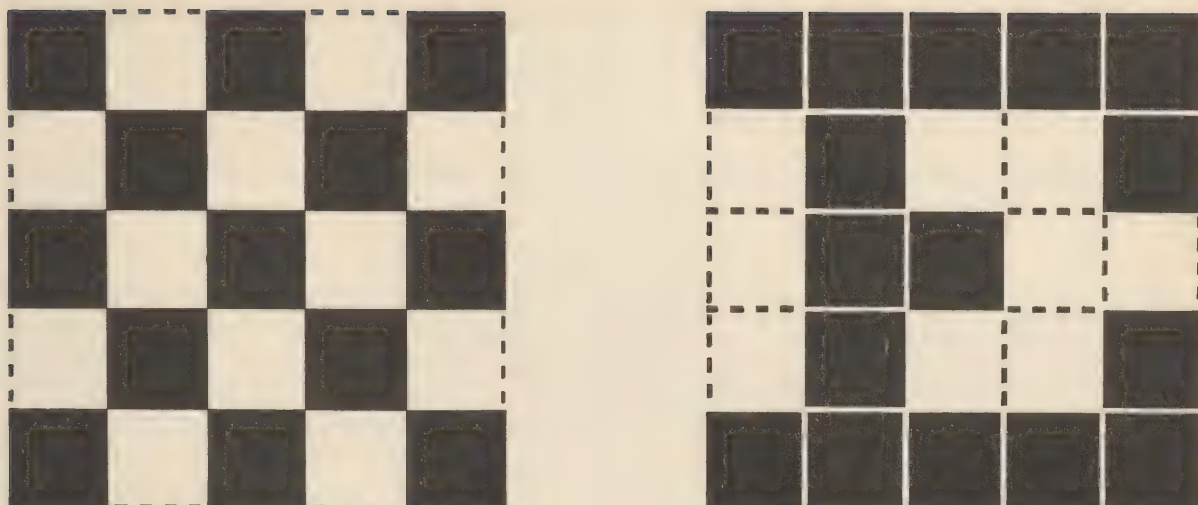


FIGURE 1.

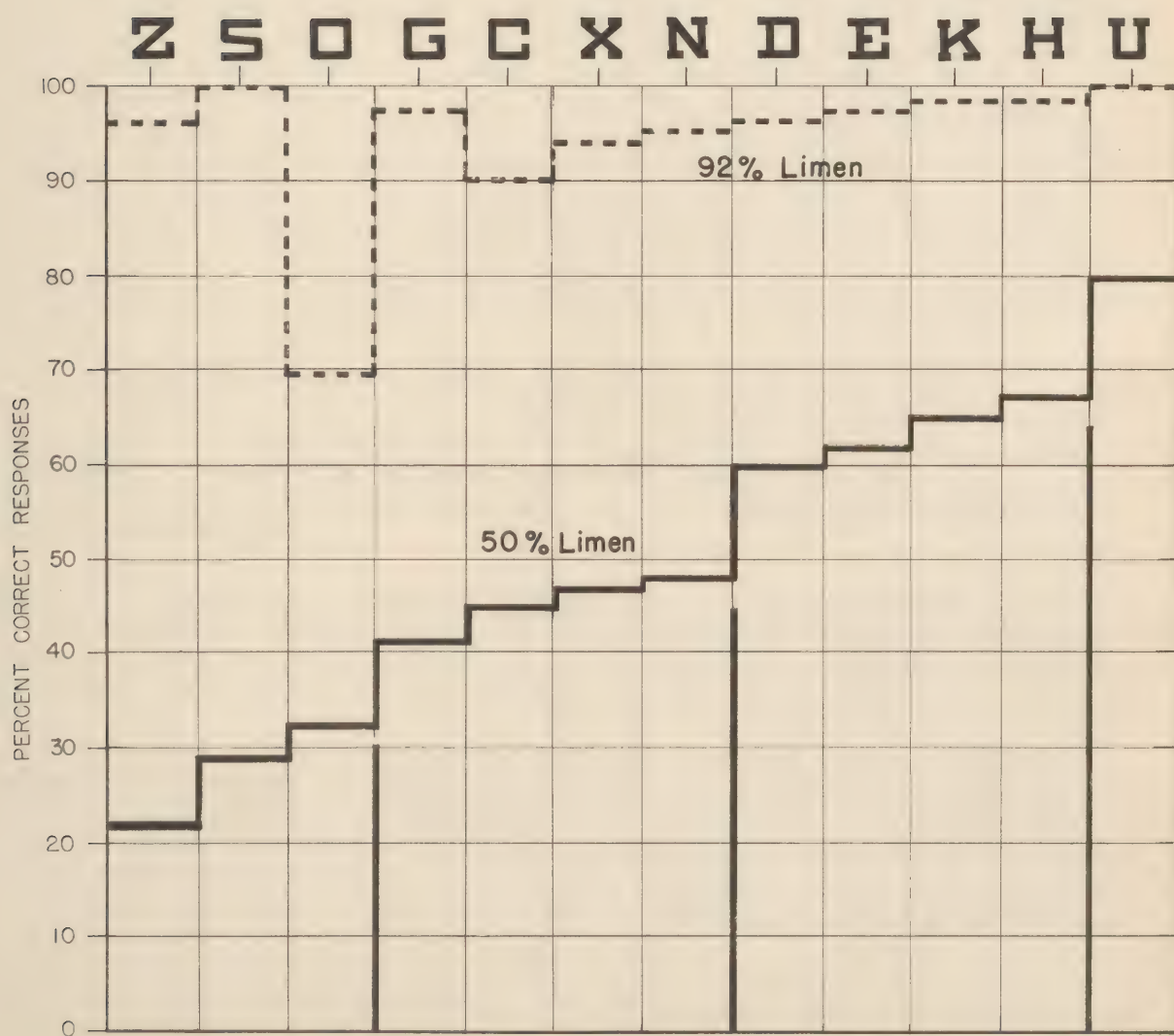


FIGURE 2.

Visual Problems in Designing Improved Indirect Lighting for Aircraft Cockpits*

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In the development of improved cockpit illumination systems for naval aircraft the major consideration is the enhancement of the pilot's performance. Two major requirements, which are somewhat conflicting, need be met in accomplishing this purpose. First, the indicators and controls in the cockpit should be made sufficiently visible in a manner free of confusing characteristics so that the pilot's activities may be carried on with adequate speed and accuracy. The second controlling requirement is that, where operationally necessary, the brightness and spectral nature of the illumination shall not interfere excessively with the pilot's dark adaptation.

Numerous studies, including those of Bromer (1) in this laboratory, have shown the superiority of red illumination over light of other spectral characteristics and also over ultra-violet floodlighting of fluorescent markings in promoting dark adaptation. More recently, a study has been made (2) in this laboratory of the effects on dark adaptation of exposure to a full panel of ultra-violet illuminated instruments which yields levels of radiant flux at the pilot's eye position comparable to those found in a survey of naval aircraft cockpits equipped with fluorescent instrument illumination. This survey of aircraft cockpits found quantitative data on the ultra-violet energy resulting from reflections from the various surfaces as well as the direct radiation in those cases where the installation is so poorly designed as to allow this condition. It was found that for brightness levels of the instrument markings adequate for legibility (from 30 to 60 microlamberts) the ultra-violet density at the pilot's eye position varied from $.4 \times 10^{-4}$ microwatts/sq cm to 3.2×10^{-4} microwatts/sq cm in the planes surveyed, except for one case of direct radiation where there were 58×10^{-4} microwatts/sq cm.

In the laboratory phase of this study, the threshold attained after viewing an ultra-violet illuminated panel yielding a radiant flux density of about 50×10^{-4} microwatts/sq cm for one hour was determined. It was found to be 0.4 log units (micro-micro-lamberts) above that attained after one hour in the dark and also 0.1 log units above the threshold level after one hour of viewing a well-designed indirectly red illuminated panel.

The Duplicity Theory gives adequate explanation of this superiority of red lighting in the nature of the photopic and scotopic visibility curves. From this mass of evidence it may be concluded that an optimal cockpit illumination technique should utilize red light with a cut-off between 600 and 620 millimicrons.

Recent Air-Force-Navy policy decisions indicate that red lighting will be brought into exclusive use in aircraft cockpits and that ultra-violet lighting will be discontinued. This decision is partly based on the results of a survey of Air Force and Navy pilots who operated Navy AD and Air Force B-17 aircraft which were equipped either with indirect red or ultra-violet lighting. As a result of piloting similar aircraft with each of the two types of lighting, a definite preference

*The opinions or conclusions contained in this report are those of the authors. They are not to be construed as necessarily reflecting the views or endorsements of the Navy. To be presented at the meeting of the Armed Forces-NRC Vision Committee, Pensacola

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for the red lighting was indicated.

It becomes necessary, then, to discover the methods for applying the red light to the useful areas of the cockpit at such brightness levels which will be additionally conducive to maximal dark adaptation. Some guiding limitations may be formulated to aid in evaluating proposed techniques:

(a) There should be a minimum of specular reflections or direct view of the light sources which would not only affect dark adaptation but would also act as glare sources causing pupillary constriction and attention localization.

(b) There should be a minimum of brightness variation among console areas and dial faces or among markings in any console area or on any dial. At the low levels of illumination to be employed, it would be undesirable to have some of the markings below the threshold of legibility or even at greatly differing supra-threshold visibility levels.

(c) The brightness level should be adjustable to provide brightnesses adequate to the state of dark-adaptation or to the ambient sky or cloud brightness. In addition, some provision may be provided to reduce the illuminated control areas to that needed for each operating situation.

(d) The brightness contrast between illuminated elements and background should not be such as to give rise to such visual difficulties as autokinesis, 'floating', or after images.

(e) Finally, the lighting system should be reasonably rugged and not too complex for ease of installation and servicing. Obviously, it should not interfere with the functioning of the controls or instruments.

The most apparent and commonly used method for cockpit lighting is floodlighting by means of directed sources. There are several ways in which this generalized lighting, even when well designed, is inadequate. At this point we need mention only that with a wide distribution of light, even on low-reflectance black-painted surfaces, there is a high enough brightness level to affect dark adaptation significantly. It should be borne in mind that the illumination level will be determined by the criterion of dial or console marking legibility, not by needs of distance orientation or contrast reduction.

Distinct from floodlighting and similar general illumination techniques, which may be called "direct lighting," are the "indirect methods." By this terminology is meant the illumination methods by which the light is confined to those small sections to which visual reference is required. In the case of aircraft instruments, the lighting in an indirect method would be confined to the dial faces rather than cover the entire panel. And to carry the technique further, the light might be confined to the individual markings and pointers. In the case of control panels, the same limitation could be made with the ultimate being the restriction of the light to the panel markings.

This laboratory has conducted a number of investigations (3,4,5,6,7) dealing with the principles which should govern the development of indirect lighting systems and has participated in the design and evaluation of such systems. The studies have been broadly separated into those of instrument lighting and those of console lighting, although many of the investigations would apply to both.

Figures 1 and 2 illustrate the day and night forward aspects of a mockup of an attack aircraft cockpit. The views show the instrument panel above and a control console directly beneath it. The illumination is designed to utilize indirect, red-filtered, incandescent light.

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In the case of instrument lighting, a practical approach to the problem would be to fashion an indirect lighting technique even though the instruments by design are intended for ultra-violet fluorescent lighting or incandescent floodlighting. For several years the Navy has made use of an installation similar to the one shown in figure 1 for single seat cockpits. A dummy panel in front of the instrument panel has openings for each of the instruments and above and between the instrument apertures are small lamp fixtures with red filters. A sponge rubber barrier separates each line of instruments. The technique affords no direct view and little specular reflectance of the sources because of the angles of incidence and view. However, the panel is tailor-made, does not allow for too much flexibility in the placement of instruments, and is not easily adaptable to two-place cockpits. In addition, the dial is set in behind the face plate yielding a 'well-effect' which produces an increased restriction to the angle of view. Visually, this panel does not always provide equality of brightness among instruments or among markings on any one instrument. Also, there is the high contrast between the dial faces and the interspaces between the dials.

Possible improvements in indirect incandescent instrument illumination have taken two major directions. The first is of immediate practicability and involves the reduction in the size of the light shield to that of an individual instrument case. This will provide for flexibility in the placement of the instruments, for large-scale procurement of standard shields, and for installation in existing aircraft models.

The other direction in which the improvement of indirect instrument lighting is proceeding is through the development of methods for entry of the light from some direction other than through the cover glass so as to eliminate cover glass reflections. Efforts to incorporate the light source within the case itself have not been as successful in the case of aircraft instruments as they have been in the case of certain shipboard and even automotive instruments. A series of experimental instrument illumination designs have been developed in this laboratory with this intention. The difficulties are largely those arising from the limitations of size, pointer torque and case pressure seal imposed on aircraft instruments. For example, many aircraft instruments could not develop sufficient torque for a plastic, light-conducting pointer.

A design which offers the possibilities of promising further development is shown in figure 3. The effect is obtained by using an external light source but allowing the light to enter the case through a pair of translucent rings. The first ring, directly under the bezel, is louvered to cause the light to be collimated parallel to the dial face and to illuminate a light weight, triangular cross-section pointer. The other ring is the dial face itself which has the dial design printed on the upper surface with translucent, white letters on an opaque, black background. Thus, the dial markings are trans-illuminated and there is a high contrast of markings to background. However, there is some reflected light to provide a low brightness level for the black dial areas. There is good evenness of illumination because of light entry around the entire ring periphery, and the panel as a whole is more uniform by virtue of the use of larger, more diffuse sources behind the panel. The 'well-effect' is eliminated. Figure 4 shows in diagrammatic cross section an instrument which incorporates this technique.

The indirect lighting of the console control panels in cockpits is currently being accomplished in the manner illustrated in figure 5. This method is the subject of Air Force-Navy Specification AN-P-89 for plastic lighting plates. Essentially, the plates used for control box facings are of 3/16 inch acrylic. The top

surface is covered overall with a translucent white paint and covered with a negative print in black. The process for producing this effect can be silk-screening, photo-etching or lamination of decalcomanias or paper prints. The other surfaces including the holes for switches, knobs, etc. are painted white followed by black. The net effect is that for daytime reading there are white markings in a black field. For night viewing the markings are red lighted from the rear by light piped from red-filtered fixtures, properly located for optimal light distribution in polished holes in the plate. A variety of schemes for internally illuminating or rear-illuminating the various knobs, handles, and pointers can be developed.

The first investigation in connection with this form of console lighting was a survey to determine whether pilots, from a preference standpoint, desire some floodlighting to accompany this high-contrast console marking illumination. Available for this purpose was the illustrated cockpit mockup built on Navy contract by The Glenn L. Martin Co. This mockup uses the edge-lighted plastic plate technique on the console. Figures 5 and 6 illustrate the differences between two of the alternative illumination techniques available to the pilot-subjects in this survey. Illumination by floodlighting alone and no lighting were also evaluated. The most noteworthy feature indicated by a comparison of the consoles with and without floodlighting is the nearly complete lack of visibility of the console knobs and switches without the added floodlighting. The results of this survey indicated that to the extent that the knobs, switches, etc. were not provided with adequate, specifically designed indirect lighting, additional low-level floodlighting was desired to highlight these control elements. An often-cited criterion used by the pilots was the importance of the controls in the area - floodlighting was desired for the more important areas. Another significant factor was the general and night experience of the pilot- the less experienced showing a greater desire for the additional floodlighting. Not emphasized greatly, but mentioned occasionally, was the opinion of some of the pilots that the additional floodlighting might aid in maintaining the 'feel' of the environment and prevent 'floating' of the markings. Significantly brought out was the fact that the floodlighting desired was at a much lower level than would be needed if it were used alone without the indirect lighting. As a result of this study, this laboratory has recommended use of low-level, uniformly-distributed, red floodlighting to accompany the indirect red console lighting. Of course, the floodlighting need be, and can be, designed to be better than that shown in the illustrated cockpit.

Next, studies were initiated of the legibility characteristics of trans-illuminated letters. The literature on visual acuity and legibility does not appear to offer a great deal on this specific perceptual problem. The problems concern the effect of size, brightness, and contrast on legibility of self-luminous markings in a dark field.

A series of legibility tests were run using naval enlisted men as voluntary subjects. A cockpit simulating enclosure, shown in figure 7, was constructed. The essential element of the apparatus is that a light beam controllable as to exposure time, color and intensity can be impinged in the rear of a translucent stimulus card. The subject remains in a light-tight enclosure with his head restrained to maintain the 28 inch distance to the stimulus. Also in the subject's compartment are cockpit-type flood lights and small point lights for directional orientation. The stimulus materials were mounted Kodalith negatives, backed with translucent Vinylite.

In the first studies made, each mounting had one line of the Navy Grown acuity test chart in one of four sizes. The task assigned to the dark-adapted subjects was to read the letters at each of four letter brightnesses with no time limitation. The results of this test series are shown in figure 8. Indicated is the different

rates at which threshold legibility changes with changing brightness. Although legibility improves with increasing size and brightness, increments of brightness may be of relatively more significance for one size of letter than for another. To avoid situations at the low brightness levels to be used in which there might be loss of legibility of some markings while others are still adequately visible, it has been recommended that all lettering on console panels be of uniform size and brightness. The ordinary criteria used for marking sizes, such as large markings for major panels and smaller markings for individual controls, etc., are satisfactory when floodlighting is used and the brightness level assures that all indices will be at supra-threshold legibility levels. However, at the near-threshold levels obtaining with indirectly illuminated consoles, these criteria cannot apply. This is borne out additionally by the consideration that the markings of individual switches indicating 'off' and 'on' are probably more critically useful and more frequently utilized than the markings for whole panels. In addition, experience has shown that a larger or brighter marking on a panel acts as a distraction and glare source.

Further legibility tests were run to determine the effect on legibility of adding red floodlighting to the trans-illumination. The black areas of the stimulus cards were found to have reflectances of about 4% and the letters about 60%. No floodlighting and three levels of red background floodlighting were used for providing comparative legibility data. The results of these tests are shown in figures 9 and 10. Adding floodlighting both reduces the contrast and, since the letters are reflecting, increases the brightness. The interaction is such that, at low levels of floodlighting, no great change in legibility occurs if legibility with only trans-illumination is already at the higher or lower extremes. For those letters at the threshold of legibility, which may be taken to be the point of 50% errors in reading, a definite decrease in legibility occurs when a low level of floodlighting is added. Higher levels of floodlighting in all cases increase legibility. It might be pointed out that when no trans-illumination is used the floodlighting level needed for legibility levels comparable to those with trans-illumination alone are higher than the highest used in these tests. This bears out the value of indirect lighting in reducing total brightness.

It might also be pointed out that some additional experimental work has shown the need for keeping the flood and indirect light of approximately the same color. Otherwise, if a color difference is added to the brightness differences between markings and other panel elements, illusory differential movement will occur under vibration. This can be attributed to the visual phenomenon called the 'fluttering heart illusion' which has been explained by differential retinal latency periods for different colors and brightnesses.

A further study is currently being conducted of the optimal form for letters, numbers and markings to be used on trans-illuminated console panels. The first part of this study dealt with the effect of stroke width on the legibility of capital letters. The nature of the letters used is shown in figure 11. The test letters were $5/32$ " in both height and width. For the tests under night conditions, five stroke widths, five levels of trans-illumination and two exposure times, $1/25$ and $1/5$ second, were employed. In this case, the dark adapted subjects were asked to read the three letters when exposed for the fixed time. The relations of the mean error scores to the stroke widths are shown in figures 12 and 13. It is demonstrated that, for the shorter exposure period, increasing the stroke width improves legibility at the low and intermediate trans-illumination brightness levels used. At the highest brightness level used, legibility is reduced after the critical ratio of 1:6 is reached. For the longer exposure time, total errors decrease but the pattern is

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changed so that at all but the lowest brightness the widest stroke is definitely worse than the narrower strokes. For the highest brightness, the narrowest stroke used is best of all. The explanation lies in the effect of 'irradiation' which is the tendency for subjective enlargement of luminous objects viewed in a dark field. Since acuity apart from the irradiation effect improves with increasing brightness, there is an interaction determining the legibility level.

Since these letters also need be read during daylight operations, a daylight test series was conducted with tachistoscopic exposure of the letters. The results of these legibility tests at two illumination levels are shown in figure 14. The three widest stroke widths are seen to be approximately the same in error scores. These data for day and night legibility indicate that the ratio of stroke width to letter height of 1:6 for letters of this form and size is optimal. In addition, considerations of dark adaptation and after-image reduction would indicate that letters of relatively wider stroke and reduced brightness would be preferable to letters of narrow stroke and higher brightness.

A similar study has been conducted to determine optimal stroke width for numerals to be used on trans-illuminated console control panels. At the same time, a study of form has been conducted using the style of AND 10400 and the style of Berger (9) for comparative recognizability tests. These numerals are shown in figure 15. In the tests they were .150" high and .09" wide. Some of the conclusions of this study are:

(a) For both daylight and trans-illumination the Berger form for numerals appear to be overall more recognizable than the AN form.

(b) The greatest disparity in recognizability is the '4' design in which case the Berger form shows a much higher recognition score. The Berger '5' and '3' are also distinctly better. There seems to be only small differences in both directions in the recognizability of the '1', '2', '6', '7', '8' and '9'. Finally, there appears to be a distinct preference for the AN form of the '0'.

(c) Of the Berger forms of the numbers, the '7', '4' and '1' are the most recognizable. The least recognizable is the '8' with the '0' and '3' following.

(d) As for the stroke width, of the three tested, a stroke width/height ratio of 1:6 appears to yield overall recognizability equal to that of the 1:8.75 ratio for daylight viewing. For trans-illumination, with the longer exposure used (1/5 sec) for three numbers, small advantages are found for the 1:15 ratio at the higher brightnesses but shifting to an advantage for the larger width at the lowest brightness used. With a shorter exposure time the advantage for the 1:15 ratio disappears even at the higher brightnesses. Since at low brightnesses there is a distinct advantage in the 1:6 ratio, and only a small advantage in the 1:8.75 ratio at the higher brightnesses, the 1:6 ratio will be recommended for the use intended.

Another study which has been made dealt with a preference survey among naval aviators for markings to be used on continuously variable intensity controls such as would be used for cockpit illumination brightness or for radio receiver volume. Figure 16 shows the alternative schemes presented to the subjects for evaluation under day and night conditions. The results of this survey indicate preference for schemes 7, 8, 9, and 11. The features of these designs which may be used as generalized criteria for markings for this purpose are:

(a) Simplicity: The elimination of all non-essential parts of the marking and reduction of the illuminated area to the minimum consistent with utility.

(b) Uniform stroke width: This attribute will help insure that no part of the marking is subjectively too bright. The stroke width should be sufficient to allow

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adequate legibility at low brightness levels, rather than the alternative of high brightness and narrow strokes. This will result in the reduction of after-images and the increase in dark adaptation.

(c) Verbal reference: The subjects showed a distinct preference for markings which do not employ geometric configurations to indicate function. Subtle indications by 'comets', lines of varying length, etc. were not desired, but rather reference by a word together with a simple arrow.

(d) Partial View: The marking should be designed to allow adequate interpretability when only a part of the marking is viewed because some of it is obscured by the knob.

Figures 17 and 18 show day and night views of a typical standard console unit designed with indirect illumination based on the principles which have been discussed. Of course, much still remains for study.

The effect of high-contrast markings on performance over extended periods is being experimentally studied in this laboratory at the present time. With respect to optimal marking forms for trans-illumination use, the studies are being extended to cover critical letter sizes, letter-height-to-width ratios and spacing. Also being investigated are the optimal forms for markings such as those on multiple selector switches, specifically whether the position indications should be on the rotating element or on the background periphery.

From what has been accomplished thus far in the developing of indirect cockpit lighting, it can be said that such methods offer a most promising avenue toward improving pilot performance.

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DISCUSSION:

Colonel Byrnes complimented Mr. Brown upon the reported study commenting that this study was a piece of work long overdue. He asked Mr. Brown whether the flood light shields were fixed so that the pilots could not throw them away.

Mr. Brown reported that the problem of flood lighting was not solved completely, but that they are definitely planning to fix the shields rigidly so that they could not be thrown away.

Colonel Byrnes then asked whether anyone has developed maps which are readable under red lights.

Mr. Brown reported that his group was not working on maps.

Dr. Hulburt commented that some Air Force people, who were working on maps for use under red light, had contacted him at NRL in recent months. He stated that he believed the people had come from Wright Field.

Dr. Chapanis reported that, in 1943, a series of maps for use under red and fluorescent lighting were developed at Wright Field. (Subsequent to the meeting Dr. Chapanis was able to locate the reports. The references are as follows:

U. S. AAF-ATSC. Engineering Division. Aero Medical Laboratory. R. C. Armstrong. Aeronautical charts prepared for use in daylight, under white, ultra-violet, red and amber lights. ENG-49-698-18, 6 Oct. 1943, 7 pp.

U. S. AAF-ATSC. Experimental Engineering Section. E. A. Pinson. Maps, charts, and photographs, fluorescent and tonal keyed for red light. EXP-M-49-695-12C, 17 September 1942, 12 pp.)

Dr. Judd suggested that charts might be arranged so that, under red light, altitude differences show up as differences in brightness, thus enabling the pilot to get an immediate impression of the altitude of various portions of the terrain.

Mr. Fisher commented that since the military departments have agreed to use red lighting it seems possible that charts will be developed soon for use under red light. Mr. Fisher commented upon the problem of shields for flood lights. He stated that a conflict always arises which is based upon the fact that it is necessary to be able to replace the floodlight lamps readily and yet it must be virtually impossible for the pilot to remove the shields. He stated that the Bureau of Aeronautics has just about reached its specifications on the shields for floodlighting fixtures.

Commander Brown expressed his interest in the problem of legibility of numerals and letters. He stated his prediction that the Berger numeral 4 would be more legible than the AND 4. He stated his further prediction that the Berger 8 would be less legible than the AND 8.

Mr. Brown commented that the 8's have not shown up as significantly different in his tests. He commented further that the 8 is the worst numeral in each of the two systems.

Commander Brown emphasized his belief that one should not feel restricted to the use

of all numerals in one system or the other, but that one should feel free to choose numerals from one or the other system in order to make a good set of numerals.



Fig. 1. Forward view in an attack aircraft cockpit with daylight illumination.



Fig. 2. Forward view in an attack aircraft cockpit with indirect illumination.



Fig. 3. Illuminated instrument illustrating effect produced with double entry edge lighting.

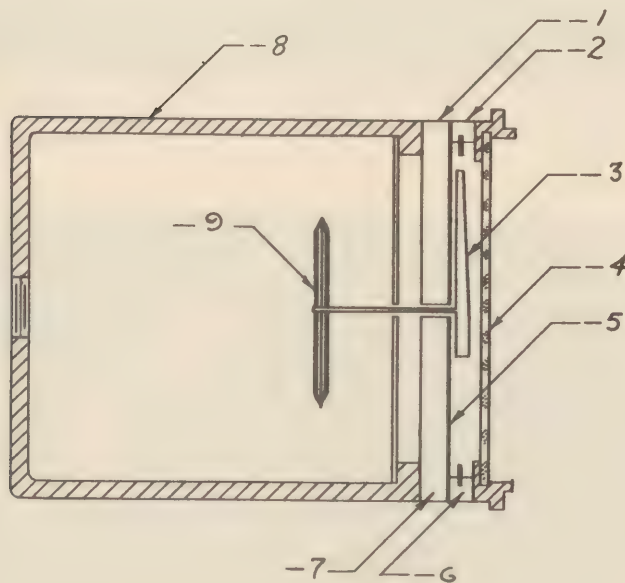


Fig. 4. Schematic cross section of instrument using double entry edge lighting:

- (1) Clear polished edge for light entry
- (2) Clear polished edge for light entry
- (3) Pointer (triangular cross section)
- (4) Cover glass
- (5) Opaque dial pattern with translucent markings.
- (6) Transparent ring with light baffle
- (7) Transparent plastic dial face
- (8) Modified instrument case
- (9) Partial representation of instrument mechanism



Fig. 5. Right hand consoles of an attack aircraft cockpit with indirect illumination only.



Fig. 6. Right hand consoles of an attack aircraft cockpit with indirect illumination and floodlighting.

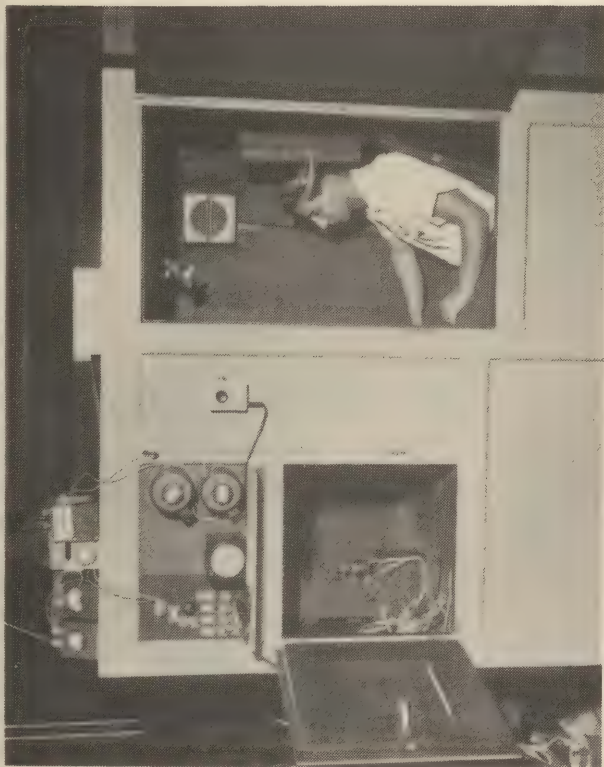


Fig. 7. Test enclosure used to present trans-illuminated test stimuli

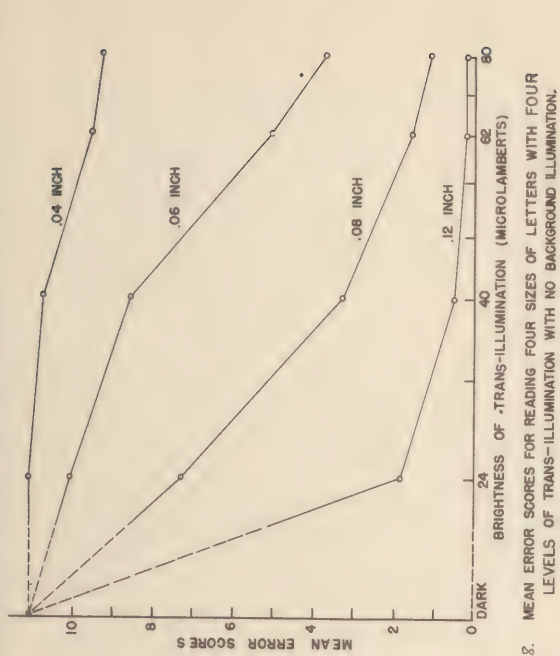


Fig. 8.

MEAN ERROR SCORES FOR READING FOUR SIZES OF LETTERS WITH FOUR LEVELS OF TRANS-ILLUMINATION WITH NO BACKGROUND ILLUMINATION.

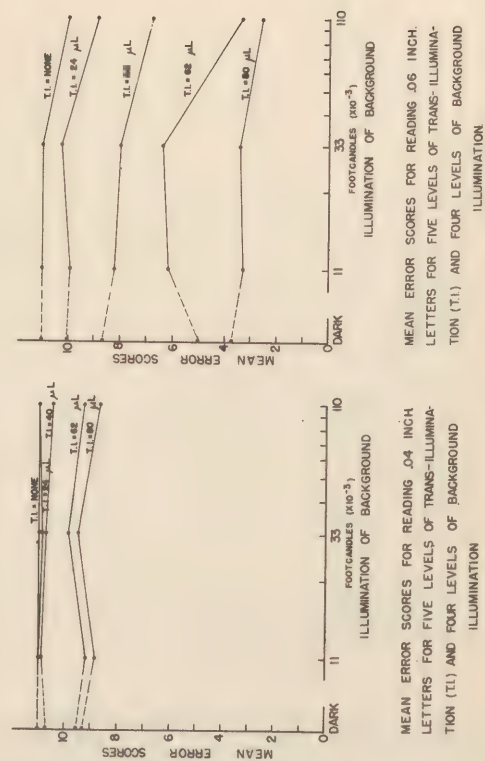


Figure 9

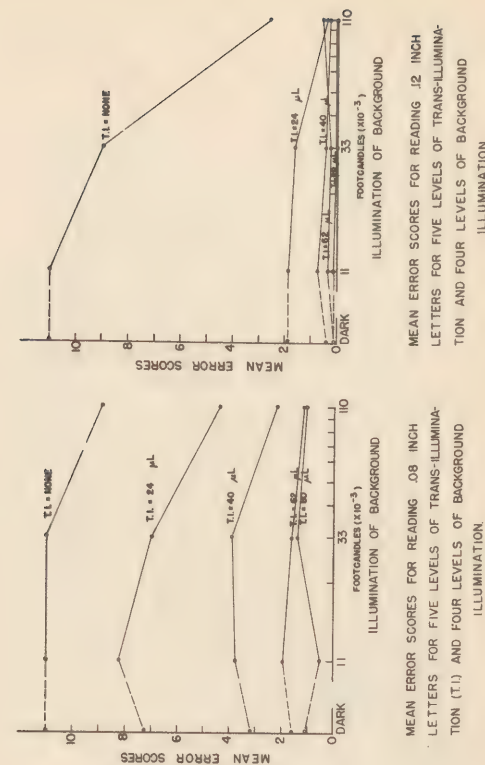


Figure 10

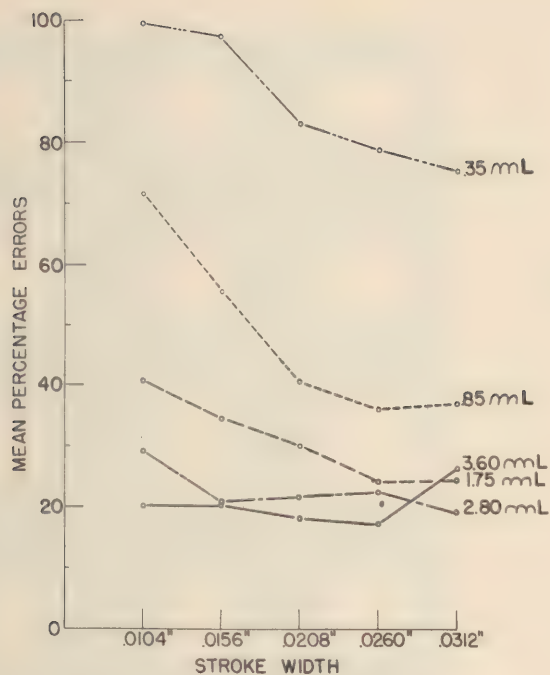


Fig. 12. MEAN PERCENTAGE ERRORS FOR READING CAPITAL LETTERS .156" HIGH—FIVE STROKE WIDTHS—FIVE TRANS-ILLUMINATION LEVELS—EXPOSURE TIME $\frac{1}{25}$ SECOND FOR EACH GROUP OF THREE LETTERS.

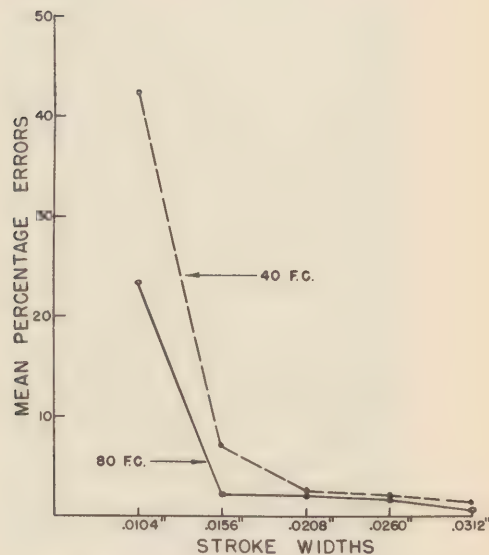


Fig. 14. MEAN PERCENTAGE ERRORS FOR READING CAPITAL LETTERS .156" HIGH—TWO LEVELS OF FLOOD LIGHTING—EXPOSURE TIME 7 MILLISECONDS FOR EACH GROUP OF THREE LETTERS.

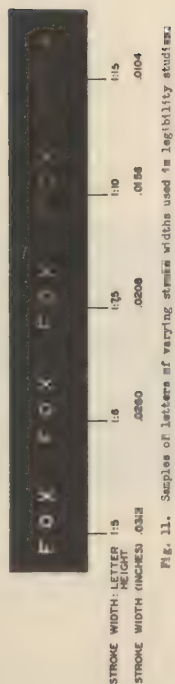
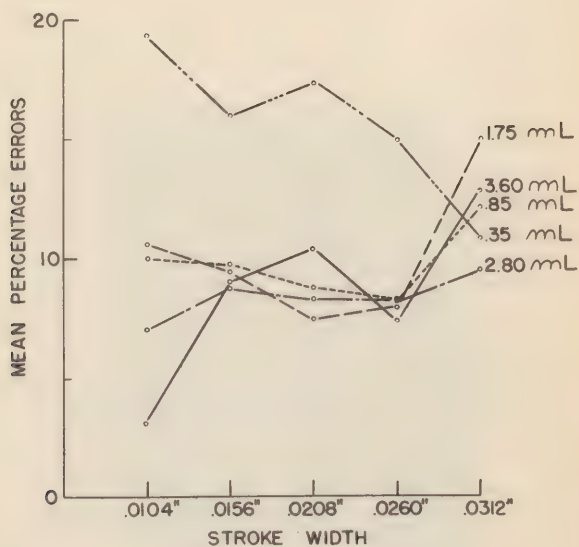


Fig. 11. Samples of letters of varying trans-illumination levels used in legibility studies.



MEAN PERCENTAGE ERRORS FOR READING CAPITAL LETTERS .156" HIGH—FIVE STROKE WIDTHS—FIVE TRANS-ILLUMINATION LEVELS—EXPOSURE TIME $\frac{1}{5}$ SECOND FOR EACH GROUP OF THREE LETTERS.

Figure 13



AND 10000 BERGER

Fig. 15. Numerals used in recognition tests-- $.15''$ in height-- $.09''$ in width-- $1:1.5$, $1:1.75$ and $1:1.6$ in stroke width/height ratio.

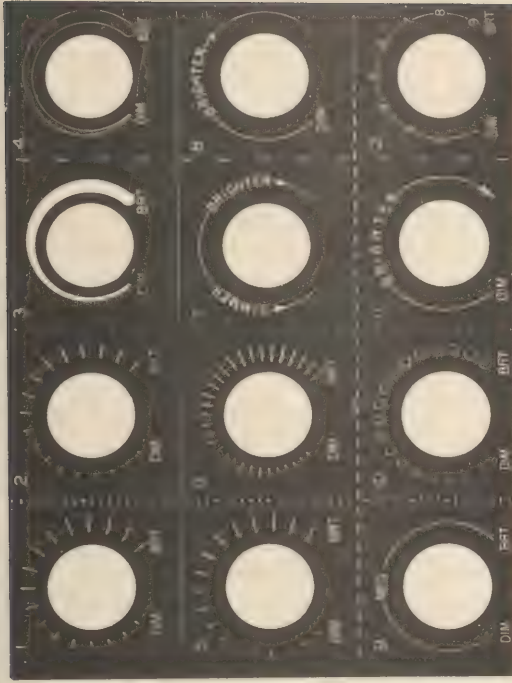


Fig. 16. Rheostat knob marking schemes used in pilot opinion survey.



Fig. 17. Daylight view of control box using plastic plate.



Fig. 18. Same control box as Fig 17 using trans-illumination and low level floodlighting.

FURTHER STUDY OF THE EFFECT OF ILLUMINATION ON THE INTERPRETATION
OF PSEUDOISOCROMATIC PLATES

by

Ingeborg Schmidt, M.D.
Randolph Field

The appearance of colored papers depends on two main qualities of the illuminating light source: (1) on the intensity, which can be expressed in terms of illumination, and (2) on the relative energy distribution of the spectrum, which for the most common light sources can be determined by the color temperature. Several authors investigated the effect of these two qualities on the interpretation of pseudoisochromatic plates. The results were worked out to be included in instructions for the use of the table tests.

Effect of Illumination

The lowest limit for plate test illumination is given by the requirement that it should not be "less than 20 footcandles." There are very few reports upon the effect of an illumination far above this limit. L. Sloan found no remarkable difference in the interpretation of the AOC tables, abridged edition, by 66 color defectives with natural daylight of 20 footcandles and artificial daylight of 60-70 footcandles. In 1948, I reported that the interpretation of the Ishihara tables by normals improved as the illumination at natural daylight increased from 30 to 150 footcandles. Yet, the interpretation of the AOC tables remained unaffected. Unfortunately, I did not determine the color temperature of the daylight used. The higher illumination might be richer in reflected sunlight; thus decreasing the errors.

To complete this problem I tried to establish the percentage of errors on the Ishihara tables, using lights of different intensity but of the same color temperature; namely, 25 and 65 footcandles at 6000°K and 25 and 100 footcandles at 11000°K. The light of about 6000°K was produced by the Macbeth Easel Daylight Lamp recommended by Farnsworth. The color temperature desired was obtained by changing the voltage. The light of 11000°K was produced by a photoflood bulb No. 2 with a Corning-Macbeth daylight roundel as used in the first lamp. The illumination of the tables was changed by varying the distance without changing the 45° angle of incidence. The tables were viewed at right angles to the subject's line of sight at a distance of 75 cm and presented for 3 seconds maximally. The Ishihara tables were chosen because I knew from my previous work as mentioned above that the Ishihara tables would show the effect in a more pronounced manner than would the AOC tables. The effect is obvious mainly on the series of tables with hidden patterns, and such hidden patterns are more numerous in the Ishihara plates than in the AOC tables. The subjects were employees and students of the School of Aviation Medicine. All of them had previously been examined with a table test at least one time. Their color vision was checked with the anomaloscope. To compensate for a certain sequence effect the subjects were divided into six (6) groups and each group was tested by following a certain scheme with different sequence of three illuminations. The tables were presented at random.

The results of the illumination effect are given in Table 1, in comparison with the results obtained by L. Sloan. This table shows that different illuminations of the same color temperature do not remarkably affect the readings of normals. On the color defectives a slight tendency to decrease the percentage of errors is obvious.

The results of L. Sloan show the same tendency on the AOC tables.

Effect of Color Temperature

As we know from some reports, the color temperature of a light source has an obvious influence on the interpretation of table tests by color defectives. Of special interest in this connection is the report of Farnsworth and Reed, and one of Hardy, Rand and Rittler. Both compared illuminations roughly and/or exactly corresponding to illuminant A and illuminant C, and found that the number of errors made by color defectives increases with increasing color temperature, which is especially evident on deuteranomalous subjects. In both reports are mentioned some deuteranomalous individuals, who passed the color plate test with illuminant A, but failed with illuminant C.

In a laboratory the color temperature of the natural daylight sometimes exceeds that of illuminant C, that is, 6500°K . In our laboratory the color temperature of the natural daylight reflected from the wall varied between 4500 and 12000°K . Farnsworth and Reed obtained in their laboratories values ranging from 3100 to 12000°K .

I tried to complete the work so far accomplished by also investigating the effect of light source with a color temperature exceeding that of illuminant C, and in this study included subjects with normal color vision. I investigated the effect of light sources of 5750°K and 11000°K , giving both an illumination of 25 footcandles on the tables. The results are shown in Table 2, in comparison with the results of Farnsworth and Reed and with those of Hardy, Rand and Rittler. From this table it is obvious that the error percentage continues to rise at color temperatures higher than that of illuminant C, too. This effect is again especially remarkable on deuteranomalous subjects, but normals also show a slight increase.

For further clarification the results are given in a diagram comprising only normal, protanomalous and deuteranomalous subjects. The individual points give the effect on persons with especially large changes in the error percentages--one deuteranomalous subject and two persons with normal color vision. At an illuminant with $11000^{\circ}\text{Kelvin}$, the one normal approaches the limit of color defectives, which is about 40 percent with the Ishihara tables. The greater differences in the values found by Farnsworth and Reed may be due to the larger number of subjects, especially of deuteranomalous ones of a lower degree, such as the one given in the diagram. Furthermore they probably used different footcandle values. Some differences in the results obtained by the authors may be due to the examiner's own way of interpreting the errors.

However, the given results justify the omission in the recent issue of the Standards of Medical Examination for Flying of the following phrase: "Since natural daylight of adequate intensity from the north sky is not available at all time ***". It is further recommended that directions for the use of natural daylight be cancelled in any instructions for use of table tests such as the Ishihara plates. The only way to get comparable results with such tables is to use a light source of standardized brightness and color temperature. The most feasible one is the New London Macbeth Easel lamp, which together with the plates constitutes a test unit that is fool proof with respect to the angle of incidence of the light and illumination of the plates. Furthermore, it meets just medium requirements as to intensity and color temperature of the light. Another reason for preferring this light source consisting of a standard 100 Watt bulb with a Corning daylight filter is its continuous spectrum. The spectrum of fluorescent daylight, for instance, shows a distinct green and a clear violet line. It is a question to be discussed whether these lines affect the reading of the plates.

In conclusion I want to report a man, who with the AOC tables made 7 errors in natural daylight of 10000°Kelvin, which means "deficient red-green color perception." On the Macbeth daylight lamp he made 3 errors, which means "normal color vision." On all other tests--SAM Color Threshold Tester, Navy Lanter, Nagel anomaloscope and a test for establishing local adaptation by Dr. P. Cibis--he attained a normal color vision rating.

TABLE I

Effect of Illumination

Foot Candles	Light Source	Mean percentage of errors on:		Subjects with normal color vision.
		AOC Tables	Ishihara Tables	
30 - 49	Natural daylight	2.3	10.3	27
50 - 85		2.9	5	42
86 - 150		2.9	4.3	31
	Artificial light color temperature in degrees Kelvin			
25	6000		8.0	40
65	6000		9.8	40
25	11000		13.04	90
100	11000		13.5	90
				Color Defectives
25	6000		82.0	11
65	6000		80.5	11
25	11000		88.6	17
100	11000		84.9	17
20	Natural daylight	74.7		66
60 - 70	15 Watt daylight fluorescent lamp	71.8		66

L. Sloan

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TABLE 2

The Effect of Color Temperature

Foot Candles	Color Temperature in Degrees Kelvin		Mean percentage of errors on:				Author and Plates
			6 Protans	27 Deutans			
	2540		69.3%	23.6%			Farnsworth and Reed - AOC 18 plate test
	6500		77.7%	56.8%			
		5 P.A.	5 P.	7 D.A.	5 D.		Hardy, Rand and Rittler - Ishihara 9 Brit. ed., 24 pl.
25	2848	88%	96%	75%	71%		
25	6750	96%	96%	79%	100%		
		90N.	5 P.A.	1 P.	9 D.A.	2 D.	I. Schmidt - Ishi- hara 8 ed., 30 pl.
25	5750	9.8%	87.5%	93.3%	76.9%	94.2%	
25	11000	13.0%	88.0%	93.3%	86.7%	96.7%	

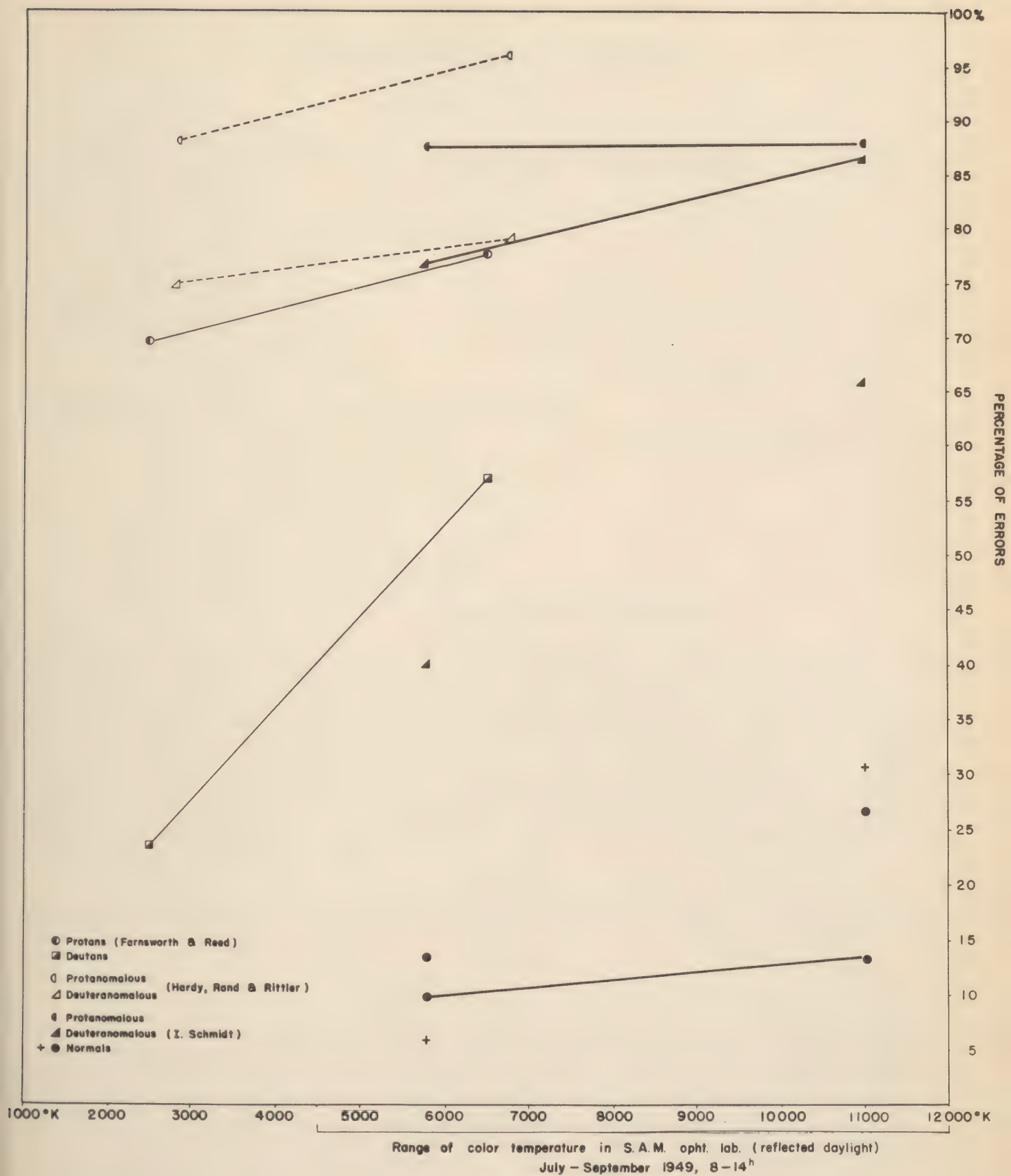
P.A. - Protanomalous subjects

P. - Protanopes

D. A.- Deuteranomalous subjects

D. - Deuteranopes

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MINUTES AND PROCEEDINGS OF THE MEETING OF
THE SUBCOMMITTEE ON VISUAL STANDARDS

June 9, 1949

A meeting of the Subcommittee on Visual Standards was held in the Pentagon Building, Washington, D. C. on June 9, 1949. The following members of the Subcommittee were present:

Dr. Richard G. Scobee, Chairman
Dr. David Freeman
Dr. Henry A. Imus
Dr. Hedwig S. Kuhn
Dr. John A. Matthews
Dr. Louise Sloan
Dr. Benjamin J. Wolpaw

In addition, the following invited guests attended:

Captain D. H. Vance, MC, USN
Colonel Austin Lowrey, Jr., MC, USA
Dr. N. C. Kephart, Purdue University
Dr. Julius Uhlener, AGO
Major Robert A. Patterson, MC, USAF
Col. Victor A. Byrnes, MC, USAF
Mr. F. W. Jobe, Bausch & Lomb
Dr. H. Richard Blackwell, Vision Committee Secretariat

The meeting was called primarily to determine recommended specifications for visual acuity test charts for adoption by the three military departments. The meeting was arranged as a result of a request received by the Subcommittee from Brigadier General John Hargreaves, Deputy Air Surgeon. Subsequent to scheduling the meeting, a request was received from Colonel Victor A. Byrnes, that the meeting also consider the possibility of recommending a change in the method of recording visual acuity scores. A third item of business was scheduled in order to take advantage of the presence of the members of the Subcommittee, namely consideration of the selection standards recommended by the Subcommittee for use by the Photogrammetric Section of the Navy Hydrographer's Office.

The meeting was called to order by Chairman R. G. Scobee at 0900. The first item for discussion concerned methods of recording visual acuity. A summary of the discussion follows:

I. Methods of recording visual acuity.

Colonel Byrnes opened the discussion by presenting several bases for his suggestion that visual acuity be recorded in terms of the angular separation of the appropriate detail of the visual acuity test object. Colonel Byrnes stated that visual acuity is essentially a measure of the minimum separable angle and that, therefore, the measure of the visual acuity should register this fact directly. Colonel Byrnes also stated that, in his opinion, the present Snellen notation is unsatisfactory for the following reasons:

1. The Snellen notation represents a fraction of the visual acuity of a theoretically normal subject. Although this assumption was the one made by Snellen, his assumption of one minute of arc as the normal visual acuity was arbitrary, and population studies since his time have clearly indicated that one minute of arc is greater than normal minimum separable, so that the fraction $20/20$ does not represent normal emmetropia. For this reason, the Snellen fraction has meaning only from tradition and suggests a relation which is untrue.
2. The Snellen notation does not transfer in comparing visual acuity at near and visual acuity at far. It has been customary to designate visual acuity at near for the "normal" as $14/14$. The practice of using a different denominator makes it difficult to compare visual acuity at near and far which is necessary for meaningful clinical interpretation. If a 20 foot denominator were used, near and distance visual acuity would become confused. Since near and distance visual acuity are not equivalent in many instances, this would lead to the possibility of erroneous diagnoses.

Colonel Byrnes concluded his remarks by recommending that visual acuity be recorded in minutes and tenths of minutes of arc angular separation of the critical detail of the test object.

Dr. Scobee remarked that the Snellen notation is difficult to deal with statistically because of the absence of sharp cut-offs. Because of inequality in difficulty between various of the Snellen letters, it is common for visual acuity to be recorded as $20/20$ minus 4 or $20/15$ plus 1, etc. Data of this sort are extremely difficult to deal with statistically. If visual acuity were recorded in minutes of arc, some sort of fractional credit could be allowed for the absence of sharp cut-offs, and a mathematically precise measure of visual acuity would result.

Dr. Scobee asked whether, if the visual angle notation were adopted, it would be desirable to utilize the angular separation of the finest detail or the angular size of the total test object. In the case of the traditional broken circle, the break subtends one minute of arc, and the total object five minutes of arc. It was the consensus of opinion of those present that the critical detail in the test object should be recorded as the angular subtense.

Dr. Wolpaw commented that it did not much matter whether minutes of arc or the traditional Snellen notations were used. He remarked that, in his opinion, the burden of proof in the change rested with those proposing the change, since any change in notational methods involves difficulties and confusion.

Dr. Uhlaner remarked that, in his opinion, the minutes of arc notation was very little better to deal with statistically than the Snellen notation. From a statistical point of view, what is needed is a scale of a human capacity which possesses equal psychological units. Visual angle does not possess this quality. It would be possible, by obtaining a distribution of visual acuity scores in the population, to build a scale of visual acuity based upon what are called standard scores. In this way a scale could be constructed which possesses equal psychological steps. The standard scale for visual acuity could be constructed upon either visual angle or Snellen notation scores.

Colonel Byrnes replied to Dr. Uhlaner by emphasizing that it was his wish to get away from designating visual acuity in terms of normal visual acuity. He stated his belief that what was needed was a meaningful physical scale of visual acuity.

Dr. Uhlaner commented that only with a standard scale is it possible to tell how many individuals have better or worse visual acuity than the patient. Dr. Uhlaner felt that for classification purposes, visual acuity notation in standard scores is essential so that meaningful interpretation could be placed upon his visual capacity.

Dr. Sloan commented that some preliminary data in her possession seemed to indicate that visual acuity expressed in terms of angular separation bears a linear relationship to diopters of refractive error. She commented that, if this relationship were found to be generally true, it would make notation in visual angle units very convenient for clinical use.

After some discussion of the points of view represented by Dr. Uhlaner and by Colonel Byrnes, it was recognized by the group that the problem of method of recording visual acuity appeared definitely dependent on whether one was concerned primarily with clinical examination or with classification of large numbers of personnel. Dr. Uhlaner, as a member of the AGO staff, is principally concerned with the classification problem, whereas Colonel Byrnes, Capt. Vance, and Col. Lowrey were all concerned with the clinical ophthalmologic aspect of the problem. Since the group had been asked to consider the problem primarily from the point of view of clinical ophthalmology in the armed services, it was felt that the point of view represented by Dr. Uhlaner should be considered as a separate problem for consideration at another time.

Dr. Scobee asked the group what the reaction of industry would be to the proposed change to a visual angle notation.

Dr. Kuhn replied that, in her opinion, the change would involve considerable complications.

Dr. Wolpaw remarked that it had taken a long time to replace the 6/6 notation by the present 20/20 notation, and he indicated his general reluctance to complicate matters further by making the additional change, unless it could be clearly shown that there was a positive gain.

Colonel Lowrey commented that the change-over would be expected to take a period of 5-10 years, but that some one should start the movement which might eventually result in general adoption of the visual angle notation.

Dr. Wolpaw asked whether it might not be wise for the question to be referred to the American Committee on Optics and Visual Physiology, since he felt that only if this group could be persuaded to accept the change would the large bulk of civilian ophthalmologists make the change.

It was suggested that Drs. Scobee, Imus, Ogle, and Berens, from the Vision Committee membership, were among the twelve members of the American Committee, and that this joint membership should provide excellent liaison. After some discussion, it was recommended that the Vision Committee Secretariat request the American Committee to consider the possibility of using a visual angle notation for recording visual acuity. It was suggested that, at the present, a visual angle notation be added to other notations at present utilized with the possibility that at some later date the Snellen notations might be abandoned. The recommendation was approved by vote of the Subcommittee. Dr. Uhlaner requested that his objection be formally recorded.

As a consequence, the Executive Secretary of the Vision Committee forwarded the

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following resolution to the Secretary of the American Committee on Optics and Visual Physiology:

AT A RECENT MEETING OF THE SUBCOMMITTEE ON VISUAL STANDARDS OF THE ARMED FORCES-NRC VISION COMMITTEE, IT WAS RECOMMENDED THAT CONSIDERATION BE GIVEN TO THE NOTATION OF VISUAL ACUITY IN TERMS OF THE ANGULAR SEPARATION OF THE CRITICAL DETAILS OF THE VISUAL ACUITY TEST OBJECT. THE VISUAL ANGLE NOTATION IS DEEMED DESIRABLE IN ORDER TO AVOID THE ERRONEOUS IMPLICATIONS OF NORMALITY INDICATED BY THE SNELLEN NOTATION OF 20/20, AND OF BETTER THAN NORMAL VISUAL ACUITY INDICATED BY THE SNELLEN NOTATION OF 20/15, ETC. IN ADDITION, THE CHANGE IS DEEMED DESIRABLE IN ORDER THAT DIRECT COMPARISON MAY BE MADE BETWEEN VISUAL ACUITY AT NEAR AND VISUAL ACUITY AT DISTANCE, A COMPARISON WHICH IS DIFFICULT TO MAKE WITH THE PRESENT NOTATION SYSTEMS. IT IS RECOGNIZED THAT A CHANGE IN NOTATION OF THIS MAGNITUDE WILL REQUIRE CONSIDERABLE TIME FOR COMPLETE ACCEPTANCE. IT IS SUGGESTED THAT, AS AN INTERIM MEASURE, THE VISUAL ANGLE NOTATION BE ADDED TO THE TRADITIONAL NOTATION, WITH THE IDEA THAT IT WILL EVENTUALLY SUPPLEMENT THE ORIGINAL NOTATION.

THE VISION COMMITTEE IS IN A POSITION TO RECOMMEND THE CHANGE IN NOTATION TO THE MEDICAL DEPARTMENTS OF THE ARMED SERVICES. THE CHANGE WOULD NOT BE DESIRABLE UNLESS CIVILIAN AS WELL AS MILITARY OPHTHALMOLOGIC PRACTICE WERE WILLING TO MAKE IT. CONSEQUENTLY, THE VISION COMMITTEE WOULD APPRECIATE A STATEMENT OF THE REACTION OF THE AMERICAN COMMITTEE ON OPTICS AND VISUAL PHYSIOLOGY TO THE PROPOSAL WITH THE IDEA THAT, IF SUCH A CHANGE WERE DEEMED DESIRABLE BY THE AMERICAN COMMITTEE, THE VISION COMMITTEE COULD RECOMMEND THE CHANGE TO THE MILITARY DEPARTMENTS.

II. Standard visual acuity test charts for the military services.

Colonel Lowrey reported that he first raised the question of standardization of visual acuity test charts by contacting cognizant officials of the Air Forces and the Navy. Joint discussion led to the recommendation that the Vision Committee be asked to provide expert advice on the problem, and General Hargreaves transmitted the request for assistance to the Executive Secretary of the Vision Committee. Colonel Lowrey discussed briefly the basis for his request that visual acuity test chart standardization be considered. He stated that, in the first place, the Army Ophthalmologists have long realized that methods employed in testing visual acuity at near are outmoded, and that an improved near vision test was, therefore, needed. In addition, Col. Lowrey stated that there appeared to be too many items in the Army Medical Supply Catalog concerned with testing visual acuity, and that, therefore, there was a real need for consolidation of the equipment into a minimum number of items. Colonel Lowrey stated further that visual acuity test charts needed to be of sufficiently durable construction so that they are semi-permanent, and so that it should not be possible for visual acuity testing to take place with cards in a semi-deteriorated condition. In addition, tests of visual acuity should measure this function primarily, not memory or other higher mental processes. Colonel Lowrey expressed his opinion that the test cards should have sufficient information on them for denoting visual acuity to satisfy civilian ophthalmologists in the military services, those interested in testing for civilian aircraft licenses, etc.

Dr. Scobee then read the letter from General Hargreaves which followed Colonel Lowrey's request for consideration of acuity chart specification. The letter is reproduced below in part:

"It is requested that the services of the Subcommittee on Visual Testing of the

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Armed Forces-NRC Vision Committee consider the problem of recommendations to the Armed Services on procurement of near vision and distance vision test cards. It is desired that the Armed Forces NRC Vision Committee obtain the services of specialists in whatever fields necessary to enable presentation of the recommendations of the committee in a form which will serve as the basis for a detailed working specification as regards tolerances, contrast, typography, fabrication, etc.

"On 15 April 1949 the following representatives of the Army, Navy and Air Force met to discuss problems of near vision and distance vision test cards for the Armed Services: Captain D. H. Vance, MC (USN); Colonel Austin Lowrey, MC (USA); Dr. Henry Imus, ONR; and Major Robert A. Patterson, MC (USAF).

"The specific characteristics desired in and the needs of the services for vision test cards were discussed. By common desire of the above representatives of the three services, it was decided to request the services of the Subcommittee on Visual Testing of the Armed Forces-NRC Vision Committee. In addition, it was felt advisable to submit to the committee for its consideration the points concurred in at the above meeting as desirable in vision test cards for service use. These points are as follows:

1. For the near vision test card:

- a. The near vision test card should be of plastic laminate construction sufficiently heavy to present a reasonable stiffness and with bosses at each corner to prevent contact of the surface of the card and subsequent scratching when it is laid on a flat surface.
- b. The letters should be photo reductions of a vision test chart to be selected by the Subcommittee on Visual Testing of the Armed Forces-NRC Vision Committee.
- c. The card should be printed on both sides; one side to be purely a near vision test card, the other to be composed of a variety of additional near vision material, such as on the Lebensohn near vision test card, as an aid to refraction.
- d. At least 3 charts would be desirable on the testing side of the chart with 10 letters on each line.
- e. The lines of test letters should be notated with various equivalents (i.e., Jaeger, Snellen Metric and Snellen English Linear as a minimum) to enable its ready use within the services during the period of transition from use of present charts.
- f. Consideration of noting 14 inch equivalents as on the American Medical Association near vision test chart might well also be considered.

2. For the distance vision test card:

- a. The minimum requirement for the Armed Services includes one folding distance chart similar in construction to the one now in the standard services vision test kit, except that it should have Snellen letters on one side and either the illiterate "E" or Landolt rings on the other. The card preferably should be finished in matte surface, plastic laminate to prevent soiling, and should be the same size when unfolded as standard distance vision test cards.
- b. For clinical use, 4 to 6 different distance visual acuity test charts should be available. It is desired that the possibility of using commercially available Snellen test charts be considered. Unless definitely worthwhile improvements are possible within a reasonable

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expenditure of time and effort, the simplification of procurement might well justify their use. If it is the opinion of the subcommittee that use of commercially available charts is not desirable, a design for 4 different Snellen test charts, one Landolt ring chart, and one illiterate "E" chart should be accomplished.

- c. All charts, including the folding chart, should conform to a standard width and length to fit a standard chart holder to be designed at a later date.

"It is hoped that when a meeting of the subcommittee is called the following individuals may be notified and attend:

Captain D. H. Vance, MC (USN) Ret.
Colonel Austin Lowrey, MC
Colonel Victor A. Byrnes, MC
Doctor Henry A. Imus
Major Robert A. Patterson, MC (USAF)."

Dr. Scobee suggested that the group consider first visual acuity test charts for distance.

Dr. Uhlener opened the discussion by emphasizing the desirability that a visual acuity test chart be selected which possesses factorial purity. With this characteristic in mind, and on the basis of the AGO study of visual acuity test charts, Dr. Uhlener recommended that the variable-grid checkerboard chart be selected.

Dr. Wolpaw reminded the group that, in its meeting of September 20, 1948, the Subcommittee had decided that a letter-type chart would be recommended for the testing of visual acuity at the present. He reminded the group that this decision had been made on the basis of the opinion that the AGO study did not indicate significant differences in reliability between the letter charts and the variable-grid checkerboard chart, and that insufficient knowledge was available upon which to base selection of a chart from a factorial point of view. He requested that the Subcommittee not reopen this matter unless there were new evidence to be brought forward at this time.

Considerable discussion by members of the group made it clear that selection of a visual acuity test chart depended upon the purpose for which the chart was to be used. If the primary purpose of the chart was for the use of clinical ophthalmologists, then the chart should have satisfactory reliability and should have empirical validity; that is, should bear a more or less obvious relationship to the kind of visual task which patients are called upon to perform. From the standpoint of classification of manpower, a chart with factorial purity has many advantages, although the proposed chart cannot be selected until military jobs for which men are being selected have been analyzed in terms of the various possible visual acuity factors. Colonel Lowrey, Captain Vance, and Major Patterson each affirmed that the interest of the military departments they represented at the present meeting were the interests of the clinical ophthalmologists, not the classification specialist. For this reason, it was the consensus of the group that the discussion at the present meeting should be concerned with the desirability of the use of various test charts for clinical examination rather than classification. The group agreed, however, that it should be made perfectly clear that the conclusion reached at the meeting would not necessarily apply to the classification problem.

Dr. Sloan pointed out that use of the checkerboard chart possessed serious

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limitations for the purposes of a clinical ophthalmologist because of the peculiar results which may be obtained with astigmatic patients. Since, with astigmatism, the checkerboard blurs in one particular orientation, the patient is able to discriminate the correct answer on the basis of cues other than those of visual resolution and, for this reason, the use of the checkerboard chart may lead to serious errors in diagnosis of refractive condition.

Dr. Wolpaw concurred with Dr. Sloan in her point of view concerning the use of checkerboard charts for refraction.

The Subcommittee reaffirmed its previous decision that, for purposes of clinical examination, letter charts should be used at the present time.

Dr. Scobee asked the group to discuss the characteristics of letter charts which should be recommended for adoption by the military services. After considerable discussion, it was decided that Dr. Sloan's proposed letter chart should be adopted in principle. This chart is based upon the notion that the same letters appear in each line of the visual acuity test chart at different sizes. This characteristic of the Sloan chart has the advantage that differences in difficulty of various letters do not enter into test results. In this way, the overlap of difficulty of successive lines of visual acuity test charts is eliminated.

After considerable discussion of the details of specifications, recommendations were adopted for the standard military visual acuity charts. These specifications are summarized below. The Executive Secretary was directed to have sample charts prepared in conformity with the recommended specifications.

I. Test chart for use at 20 feet.

- a. The chart is to be printed on a matte plastic material which will withstand washing.
- b. Snellen-type (block) letters are to be employed. The following letters should be used:

N K R C S Z V O D H

They are to be arranged in random order.

- c. Each row is to be numbered at the left-hand side of the chart in Snellen-size (20/50) numerals.
- d. Three designations of acuity are to be printed at the left-hand side of the chart beside each row of letters. These are:
 1. Snellen-size
 2. Visual angle size
 3. Visual efficiency
- e. The chart is to be printed on both sides. One side should contain:

Row 1.	5 letters (size 20/50)
Row 2.	5 letters (size 20/50)
Row 3.	10 letters (size 20/40)
Row 4.	10 letters (size 20/30)
Row 5.	10 letters (size 20/25)
Row 6.	10 letters (size 20/25)
Row 7.	10 letters (size 20/20)
Row 8.	10 letters (size 20/20)
Row 9.	10 letters (size 20/20)
Row 10.	10 letters (size 20/20)
Row 11.	10 letters (size 20/15)
Row 12.	10 letters (size 20/15)

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Row 13. 10 letters (size 20/12)
 Row 14. 10 letters (size 20/10)

The opposite side should contain:

Row 1. 2 or preferably 3 letters (size 20/200)
 Row 2. 4 or preferably 5 letters (size 20/100)
 Row 3. 5 letters (size 20/70)
 Row 4. 5 letters (size 20/70)
 Row 5. 5 letters (size 20/50)
 Row 6. 5 letters (size 20/50)

- f. If feasible, the printed lines should be so arranged that some charts may be cut, hinged, and folded to permit storage in medical field chests.
- g. The size of the chart should approximate that of the presently available distance visual acuity test chart of the American Optical Company (30 x 60 cms).

II. Illiterate visual acuity chart for twenty feet. While it is recognized that there is need for an illiterate chart, the need is comparatively small and does not justify the cost of construction and procurement of new charts by the Armed Forces. The Illiterate-E Chart now available commercially is believed to be perfectly satisfactory for the purpose.

III. Visual Acuity test chart for fourteen inches.

- a. The chart is to be printed on plastic material similar to the material used for the distance acuity chart.
- b. The chart is to be printed on both sides. One side should contain:
 On one half, an exact duplication of the entire chart for 20 feet (both sides; 20/200 through 20/10).
 On the other half, an exact duplication of the presently available Illiterate-E Chart.

Each line to be designated as on the distance chart in terms of Snellen notation (14/14), visual angle, and visual efficiency.

The other side should contain:

- Selection of lines of words, two lines of each size of type ranging from 12 point to 2 point type (as on the present Lebensohn chart).
- c. Chart to have 5 metal-rimmed eyelets, one in each corner and one in the center at the top 1/4 inch from margin. Corner eyelets are to support card surface off of table; center eyelet at top is for attachment of string marker for 14 inch distance if that is desired.

III. Program of operator selection, Navy Hydrographer's Office.

After adjournment of the main Subcommittee meeting, a working group composed of Chairman Scobee, Dr. Henry Imus, and Dr. N. C. Kephart met with Mr. M. H. Salzman of the Photogrammetry Section of the Navy Hydrographer's Office to discuss further developments in the operator selection program organized by recommendations of members of the Visual Standards Subcommittee. A preliminary and unofficial report of the Subcommittee consideration of the photogrammetry selection problem is contained in the Minutes and Proceedings of the 23rd Meeting of the Armed Forces-NRC Vision Committee, pages 59-62. A supplementary official report of the working group is contained in the letter of May 5, duplicated below, from chairman Scobee to Captain C. W. Shilling.

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"On 24 December, 1948, the Hydrographer addressed a letter to the Office of Naval Research. The letter was a request for the Vision Committee to advise on a method of selection of employees for a contemplated expansion program in the Photogrammetry Section of the Hydrographer's Office. This request was forwarded to the Vision Committee on 10 January, 1949, and was considered by the Subcommittee on Visual Standards. The results of the subcommittee's deliberations are herewith transmitted to you as official representative of the Department of the Navy on the Armed Forces-NRC Vision Committee.

"The Subcommittee requested that a preliminary study be made upon present employees in the Photogrammetry Section as well as upon all available employees in the government service performing similar work. This study included an orthorater profile, an ophthalmologic examination, and an efficiency rating. Data were secured from 27 subjects, all presently employed and of varying years of experience. Some of the efficiency ratings were not properly done and it has been requested that they be repeated using the method of paired comparisons. Blanks for this are being sent to Dr. Imus by Dr. Kephart. On the basis of the data, the following recommendations are made:

"1. A tentative orthorater profile for selection of prospective personnel has been constructed. Dr. N. C. Kephart of Purdue University is making a transparency of the master profile and will forward it to you in the immediate future. It is recommended that all prospective employees be studied on the orthorater; if they pass this test, no subsequent visual examination is believed necessary, but they may proceed to the work sample test suggested in paragraph 5.

"2. It is recognized that the number of applicants for employment under the proposed expansion plan may be limited. For this reason, some further test is indicated for those prospective employees who fail the orthorater test if available positions are to be filled promptly. An ophthalmologic examination is necessary for further and more refined screening of this group. The examination should include a cycloplegic refraction with the prescription of suitable lenses where indicated. Any of the following findings are suggested as being disqualifying from further consideration for employment:

- a). Anisometropia greater than two diopters when calculated on the basis of spherical equivalent of the refractive error.
- b). Visual acuity not correctible to 20/20 in each eye separately.
- c). Any active ocular disease (the detailed interpretation of this should be left to the discretion of the examining ophthalmologist).
- d). Heterophoria. (Maddox rod test)
 1. At 20 feet, either esophoria or exophoria of more than 4 prism diopters or hyperphoria greater than 1 prism diopter.
 2. At 13 inches, esophoria greater than 5 prism diopters, exophoria greater than 10 prism diopters, or hyperphoria greater than 1 prism diopter.
- e). Prism divergence at 13 inches of less than 12 prism diopters or greater than 25 prism diopters.

"3. It is realized that few Navy funds are available to cover ophthalmologic examinations of prospective employees who fail the Orthorater test. It is, therefore, suggested that muscle balance studies, visual acuity determinations, and then a cycloplegic refraction be done by the ophthalmologist at the Naval Gun Factory. If this first examination indicates that the candidate cannot pass the limits suggested in paragraph 2, the examination should be stopped at this point and the candi-

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date so informed. The Department of the Navy would bear the expense of the examination. On the other hand, if the examination indicated that the prescription of proper lenses might enable the candidate to be employed, a post-cycloplegic examination should be done and the candidate required to pay the expense of the entire examination.

"4. If correcting lenses are given as described in paragraph 3, the candidate for employment should be required to wear them for a minimum of two weeks before proceeding to the last test as described in paragraph 5.

"5. The final test prior to employment should be a work test. It is believed that some relatively simple "on the job" performance test be devised by the Photogrammetry Section. This has been discussed with Mr. Salzman of the Section and appears feasible. The final decision as to employability and suitability of an applicant would depend upon this test.

"6. In the past war, the Bausch and Lomb Mark II Stereotrainer was utilized for selection of stereoscopic range finder operators with good results. The stereotrainer has not been employed for purposes of prediction of ability of potential employees in the Photogrammetry Section. It is possible that the two tests are similar enough that the stereotrainer might be worthwhile. It is suggested that this possibility be explored in view of the fact that not only is the instrument available but that the method of administration of the test has been standardized in the form of a manual.

"7. An appreciation of visual criteria is essential for evaluation of prospective employees. It is recommended that Mr. M. H. Salzman of the Photogrammetry Section be sent to the next session of the Industrial Vision Institute at Purdue University; the dates are July 11-16, 1949. Tuition is \$75.00 and application should be sent to Dr. Joseph Tiffin, Purdue University.

"8. The Subcommittee on Visual Standards will meet in Washington on June 9, 1949. A progress report from the Photogrammetry Section would be welcomed by the subcommittee at that time. The revised efficiency ratings previously mentioned can be considered then."

At the June 9 meeting, the material requested in the letter of May 5 was presented by Mr. Salzman and by Dr. Kephart. As a result of deliberations of the working group, the following report of the meeting was prepared and transmitted to Captain Shilling by Chairman Scobee by his letter of June 21, duplicated below:

"At a meeting of the Subcommittee on Visual Standards of the Armed Forces-NRC Vision Committee held in Washington on June 9, 1949, Dr. Henry Imus and Mr. M. H. Salzman presented the additional data requested in my letter to you of May 5, 1949. You will recall that we had been requested to consider the problem of selection of personnel in an expansion program in the Photogrammetry Section of the Hydrographer's Office. On the basis of the additional data made available, the Subcommittee is herewith submitting final recommendations.

"The added data did not change any of the suggested limits for visual performance but merely served to confirm speculations of the Subcommittee. The method employed in setting up a selection program was a type of job analysis together with a study of the visual characteristics and efficiency ratings of those presently employed in this type of work. An analysis of the Orthorater ratings is attached and was prepared by Dr. N. C. Kephart, Occupational Research Center, Purdue University.

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Clinical examination data were analyzed by myself. In instances where the clinical judgment and Orthorater judgment were at variance, retesting was requested. Clinical examinations were performed by Dr. Henry J. Hoff who is, I understand, under contract to the office of Naval Research.

"It is of interest to note that in the majority of instances in which the Orthorater findings varied from those of the clinical examination, a retest revealed that the original Orthorater reading was probably the correct one. The chief discrepancies occurred in the Maddox rod determinations of heterophoria at the reading distance in the clinical examination.

"With respect to presently employed personnel, it is suggested:

1. That Miss Anne Montgomery be advised to secure reading glasses for use in her work.
2. That Mr. Earl Leonardo have his glasses changed, particularly the left lens.

It is believed that while the work of these two is satisfactory, it will be appreciably improved if the above changes can be made.

"The Orthorater profile for selection of prospective employees in the Photogrammetry Section is already in the hands of Mr. Salzman, having been forwarded to him by Dr. Kephart. The Subcommittee suggests that prospective personnel who do not fall within the Orthorater profile be further processed in accordance with paragraphs 2, 3, 4, 5 and 6 in my letter to you dated May 5, 1949.

"Speaking for the Subcommittee, may I say that we have been very much interested in working on this problem and shall be glad to be of further assistance in any way possible. We would appreciate hearing from the Hydrographer at some later date when the selection scheme has been actually tested in use."

ANALYSIS OF THE ORTHORATER RATINGS

by
Occupational Research Center
Purdue University
West Lafayette, Indiana

Company Navy Hydrographic Office

Profile No. _____ Job Photogrametrist

DIFFERENCE IN JOB PERFORMANCE

Criterion:

Ratings

Experience:

Criterion	Total group		Those who meet all primary standards		Those who do not meet all primary standards	
	NO.	%	No.	%	No.	%
Rated Above Average	9	53%	4	67%	5	45%
Rated below Average	8	47%	2	33%	6	55%
Total:	17		6		11	

Among present employees who meet all indicated standards 67% are rated high and 33% are rated low; but among those who do not meet the same standards 45% are rated high and 55% are rated low.

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DISCUSSION of the Report of the Subcommittee on Visual Standards:

Dr. Imus commented upon the use of plastic for the near acuity chart. He referred to objections which had been raised by materiel personnel in the Navy concerning the use of a fused plastic process. It had been reported that the fusing process distorts letters to an unallowable extent. Dr. Imus reported that he had been satisfied that the process of imprinting letters on plastic will result in satisfactory definition of letters for a near acuity chart. Dr. Imus further commented that he could not see the need for a 20/400 visual acuity chart for use in the field.

Lt. Rand asked why a separate chart for clinical, and for selective use was necessary.

Dr. Scobee commented that the principles involved in selection and those involved in refractive are sufficiently different so that separate charts are necessary.

Dr. Imus added that it was the Subcommittee's belief that a machine screening device would soon be in use for recruiting purposes. With these devices in use, the chief use for visual acuity test would be for clinical refractive purposes.

Commander Farnsworth asked what the advantages of the new chart were over presently available charts.

Dr. Scobee replied that this chart was the joint product of all interested parties in the Armed Forces and it, therefore, represented all the changes which they deemed desirable in charts for military use.

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THE VISION COMMITTEE TRIP ABOARD THE USS CABOT

Members of the Vision Committee departed from the Officer's Quarters at 6:45 a.m. Tuesday, November 15. The trip to the docks where the USS Cabot was moored was made by Navy bus.

Perhaps the most notable aspect of the Vision Committee invasion of the USS Cabot was the fact that three women members of the Vision Committee were permitted to go aboard ship. The female invasion was made possible by the effective maneuvering of Dr. Hedwig Kuhn. Because of the rarity of women going aboard a Navy vessel, members of the Committee were made to feel that they were a part of a distinguished group.

The Vision Committee group was soon taken below decks where they met Captain Lee, Commanding Officer of the ship, and Commander Merrick, Executive Officer. The ship was soon under way and the Vision Committee adjourned to the flight deck where they proceeded to ask the usual kind of "landlubberish" questions of the available Naval personnel. The ship proceeded uneventfully out of the harbor, and out on the high seas, whereupon the training craft began to land. Vision Committee members remained in the safety of the superstructure, while a number of pilots made the required six qualification landings each.

Morning coffee, and later an ample luncheon, were supplied the Vision Committee members in the Ward room, while the ladies enjoyed the facilities of the Captain's cabin. The Executive Council hid away in a small cabin during the early afternoon and discussed weighty policy matters while the qualification landings continued overhead.

After the landings had been completed, the Vision Committee was treated to a Navy style floating movie performance in the Ward room. Excellent documentary films were shown which demonstrated the Navy's interest in such topics as the landing in the Aleutians, the reconquest of the South Pole, and the exploration of the implications of the atomic bomb.

Vision Committee members were active with their cameras, as would befit such a photographically minded group. The attached photograph shows the flight deck of the USS Cabot with 4 air craft aboard. The other photographs were taken after the group had disembarked from the Cabot and were proceeding shoreward. The right hand figure exhibits Lt. Comdr. Dean Farnsworth in a photographic pose. (These photographs were taken by Dr. R. A. Woodson).

The Committee felt much appreciation to Captain Lee and his men for a truly memorable day.



A B S T R A C T S237. A Low Cost Boundary Lighting System for Small Airports.

M. S. Gilbert

U. S. Department of Commerce, Civil Aeronautics Administration, Airport Development Division, Technical Development Service, Washington, D. C.
Technical Development Report No. 53, August 1947, 12 pp., (0)

"This report describes the development of a low cost two-color gaseous tube boundary lighting system as installed at Aretz Airport, a privately owned and managed air field at Lafayette, Indiana.

"Based on experience gained in maintaining two-color boundary lights installed at the Civil Aeronautics Administration Experimental Station at Weir Cook Municipal Airport, Indianapolis, Indiana, a new lighting-unit design was suggested by the author. A development contract was entered into with the Leland Electric Company at Dayton, Ohio, whereby ten of these units were furnished for a trial installation which was made by Civil Aeronautics Administration personnel at Aretz Airport under a contract with the owner.

"It was found that such an installation complete with obstruction lights, poles, lighted wind cone, miscellaneous wiring material, underground cable and ten two-color boundary lights could be made for approximately \$2600.00, provided the owner purchased all material himself and hired union labor to do the work. If contracted the installation would cost appreciably more, depending upon the net profit of the contractor.

"Judging from available data the electrical energy to operate the installation should cost an average of 15 cents per hour.

"Preliminary flights showed the lights to be distinctive in appearance and definitely discernible from an altitude of 1000 feet and from 15 to 18 miles distance during unlimited visibility weather. The lights as designed are suitable for rectangular fields but may be difficult to interpret on many-sided fields, in particular those which are L-shaped or T-Shaped."

238. Some Considerations of High Intensity Approach Lighting.

H. J. Cory Pearson, and Gilbert, M. S.

U. S. Civil Aeronautics Administration, Technical Development,
Indianapolis, Indiana.

Technical Development Report No. 60, October 1948, 13 pp. (0)

"This report discusses the high intensity approach lighting problem and various types and applications of lights that are being offered as solutions to the problem.

"It shows that under conditions of restricted visibility a light having a relatively moderate candlepower value can be seen from a certain maximum distance. As this candlepower is multiplied many times, the distance from which the light can be distinguished is increased very little, until a limit is reached beyond which it is impractical to increase the candlepower. There are other factors which enter into the case. The background illumination is very important, as a light that could be seen against a bright background such as prevails in daylight would be so uncomfortably glaring as possibly to blind a pilot trying to land at night with lamps of that brightness, and, conversely, lights of proper brilliancy for normal night fly-

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ing would be invisible under daylight conditions. These facts, known to engineers, determine the limits to which the designer may go in selecting his tools for solving the problem.

"It is obvious that there is need for brightness variation control to provide adequate brightness for visibility under diverse conditions, such as those prevailing during daytime fogs as compared with nighttime.

"Various approach lighting systems that have been or are being tried out are discussed and criticized. The old systems had faults which the new systems attempt to eliminate by various means. There are different methods for accomplishing the same results.

"The only system which attempts to indicate to the pilot his position with respect to the glide path is the proposed CAA slope-line system. This is thoroughly discussed and explained.

"With the aid of knowledge gained through exhaustive experimentation, it is believed that the engineering profession soon will find the optimum solution to the approach light problem."

239. A Study of the Legibility of Trans-Illuminated Markings in Aircraft Cockpits.

F. R. Brown

U. S. Aeronautical Medical Equipment Laboratory, Naval Air Experimental Station, Naval Air Material Center, Philadelphia, Pennsylvania.

Report TED No. NAM EL 600, Part 2, 25 February 1949, 33 pp., (0)

"Series of tests have been conducted to determine the principles governing the legibility of red trans-illuminated Grow Chart letters under conditions simulating those encountered in reading markings on new type aircraft cockpit console panels. Seventy-five subjects read the letters from a distance of 28" in the dark under conditions of dark adaptation. The variables in the tests were letter size, brightness of trans-illumination and level of background floodlighting. In the range of variables employed in the tests, legibility, as measured by the reading error scores, improves with increasing size and brightness of trans-illumination. However, the rate of improvement of legibility varies so that at certain sizes and brightnesses relatively small changes in these variables yield relatively large changes in legibility. It is concluded, therefore, that uniformity in size and brightness of markings on console panels would insure that the legibility of all markings will vary uniformly as the brightness is changed. Uniformity of change of legibility would prevent a situation in which some of the markings might be at a useful level above the threshold of legibility while others might be significantly below the threshold. When a low level of red background floodlighting is added to these trans-illuminated panels, no significant change in legibility occurs, if legibility is already at a very low or very high level. But for intermediate levels of legibility (near 50% reading errors) the added low level floodlighting reduces legibility significantly by reducing the brightness contrast ratio. High level floodlighting increases legibility in all cases. It is concluded from this that uniformity of floodlighting on these panels would result in equal changes in legibility for all the trans-illuminated markings as the floodlighting level is changed."

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240. Development of Airport Control Tower Lighting.

M. S. Gilbert

U. S. Civil Aeronautics Administration, Airport Development Division,
Technical Development, Indianapolis, Indiana.

Technical Development Report No. 82, April 1949, 17 pp., (0)

"This report describes the development of a method for lighting airport control towers.

"Earlier experiments with "black" or ultraviolet light were carried on at the Richmond, Virginia, control tower. Instruments and dials were painted with fluorescent paint which made them visible under the ultraviolet light, while allowing the eyes of the tower operators to remain dark-adapted. Also included in these experiments was a study of the use of red light for tower lighting. Operations were later transferred to the airport control tower at Weir Cook Airport, Indianapolis, Indiana, where experiments were continued with ultraviolet, red, and white light in various applications. The recommendations for the airport control tower lighting plan discussed in this report were made after a study of the results of these experiments.

"This plan involves the use of ultraviolet; also white and/or red light at the discretion of the tower personnel in order to allow for different psychological reactions among the various people. The tower is divided into seven working areas and specific treatment is recommended for each area."

241. The Perception of the Postural Vertical

Cecil W. Mann, and Berry, Newell H.

Joint Project Report No. 5, The Tulane University of Louisiana, Contract N7onr-434 T. O. I; Office of Navy Research, Project Designation No.

NR 140-455; U. S. School of Aviation Medicine and Research, Project

No. NM 001 037. Report No. 2 Visual Factors, 23 June 1949, 11 pp. (0)

"Under the conditions of this experiment there was no significant difference in the precision of the individual's judgment of the visual vertical and visual horizontal.

"As in a previous investigation, the mean errors and variability of judgment are significantly increased when a soft padded seat is substituted for a hard seat.

"The mean error and variability of the judgments of the visual horizontal are significantly greater when the individual is in a position of tilt than when he makes the judgment from a vertical position."

242. The Delay in Visual Reorientation Following Exposure to a Change in Direction of Resultant Force on a Human Centrifuge.

Capt. Ashton Graybiel, and Brown, Robert H.

Joint Project Report No. 3, The Tulane University of Louisiana under Contract N7onr-434 T. O. I; Office of Navy Research, Project Designation No. NR 140-455; U. S. School of Aviation Medicine and Research, Project No. NM 001 037. Report No. 1, 6 pp. (0)

"Three subjects were exposed on a human centrifuge to a change in direction of resultant G relative to the body axis. Under the conditions of the experiment the illusion was created wherein a horizontal target line appeared to rotate through an angle corresponding to the change in direction of the resultant force. The subject's task was to keep the line horizontal at all times. Thus, if the line appeared to

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rotate clockwise, the subject actually rotated the line counterclockwise in order to maintain the line horizontal for himself. A marked discrepancy was noted between the time required to impress the physical force on the subject and the period during which he found it necessary to make adjustments in keeping the line horizontal. This discrepancy was regarded as a measure of the delay in the subject's visual reorientation to a change in direction of resultant G. It is thought that a possible cause of the delay may lie in the characteristic behavior of the otolith organ. This lag phenomenon is of importance to aviation inasmuch as the full disorientating effects of a change in direction of resultant G relative to the body axis will not become manifest if the exposure time is short."

243. The Relationship Between Apparent Displacement and Motion in the Oculogyral Illusion.

Robert H. Brown; Imus, Henry A.; Niven, Jorma I.; Graybiel, Captain Ashton. Joint Project Report No. 1, The Tulane University of Louisiana, Contract N7onr-434 T. O. I.; Office of Navy Research, Project Designation No. NR 140-455; U. S. School of Aviation Medicine and Research, Project No. NM 001 002. Report No. 1, 1 May 1949, 5 pp. (0)

"Under the proper conditions, angular acceleration gives rise to a well-defined apparent movement which has been termed the oculogyral illusion. This illusion comprises apparent displacement of a visual target as well as apparent motion. In the case of an object in actual motion, real displacement, that is, change in position, has a very definite relationship in duration and magnitude to the causal motion. On the other hand, the illusory displacement reported here, as observed during apparent motion, does not obey such precise or meaningful laws. The relationship between these two characteristics was studied by rotating 12 subjects in a Link Trainer at 26 rpm for one minute. They were then decelerated to 0 rpm rapidly. During and after rotation the subject's head was maintained at a fixed 15 degree forward inclination. The target was observed only during the last 15 seconds of rotation and until the illusory effects subsided; the eyes were closed during the initial 45 seconds of rotation. Each subject was given 5 trials at 7 minute intervals per day and 10 daily sessions. One half of the subjects reported on motion phenomena in the first 5 sessions and displacement phenomena in the second five sessions. This order was reversed for the remaining subjects.

"In general, the target was observed as displaced and always in the direction of apparent movement. There were, however, large individual differences in reports of amount and duration of apparent displacement. For those who experienced apparent displacement of the target, the illusion persisted briefly after the apparent motion had ceased. Correlations of independently-observed nystagmus was related to both. The relationship was more significant for motion than displacement. Habituation, i.e., decline in duration of motion or of displacement, either from trial to trial or day to day was not noted for these experimental conditions."

244. A Study of the Applicability of Indirect Illumination Methods to Individual Aircraft Instruments.

F. R. Brown

U. S. Aeronautical Medical Equipment Laboratory, Naval Air Experimental Station, Naval Air Material Center, Philadelphia, Pennsylvania.
Report TED No. NAM EL-318, 4 May 1949, 15 pp., (0)

"A number of indirect illumination methods devised for use with certain individual shipboard instruments have been examined and evaluated to determine their applicability to aircraft instruments. Considerations of size, weight, available

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pointer torque, and pressure seal of instrument case are opposed to direct application of these shipboard instrument lighting methods to aircraft instrument use. The problem has been further investigated by fabricating and evaluating a series of nine instrument face mock-ups to determine whether other indirect lighting techniques could be developed for aircraft instruments. From a consideration of the requirements of an ideal aircraft instrument lighting method, when related to the demonstrated features of the mock-up instruments, it is concluded that most of these designs do not fully meet these requirements. However, one instrument using an external light source and double windows of translucent plastic gave a good illumination effect and this might offer a possibility for further development."

245. A Study of the Requirements for Letters, Numbers and Markings to be Used on Trans-Illuminated Aircraft Control Panels. Part 1. The Effect of Stroke Width Upon the Legibility of Capital Letters.

F. R. Brown, and Lowery, Edward A.

U. S. Aeronautical Medical Equipment Laboratory, Naval Air Experimental Station, Naval Air Material Center, Philadelphia, Pennsylvania.

Report TED No. NAM EL-609, 26 September 1949, 19 pp., (0)

"A series of studies, of which this is the first, are being conducted to determine the requirements for letters numbers and markings to be used on trans-illuminating control panels in the cockpits of military aircraft.

"This study reports experiments on the effect of varying stroke width upon the legibility of capital letters of fixed height and width. The other variables were brightness of red trans-illumination, the level of floodlighting simulating daylight, and time of exposure. The tests were made under conditions approximating those encountered in aircraft cockpits.

"The results indicate that for the shorter exposure period used, increasing the stroke width improves the legibility at low and intermediate trans-illumination levels, but that legibility is reduced after a critical width is reached at high trans-illumination levels. For the longer exposure time, total errors decrease relative to the shorter time, but the pattern of errors for the higher brightnesses is such that there is decreased legibility with the wider strokes. At the intermediate brightnesses, a wide range of stroke widths show no differences in legibility. For daylight reading, within the range tested, widening the strokes improves legibility but with decreasing increments of improvement for the greater widths.

"From an analysis of these data, it is found that a stroke width/height ratio of 1:6 is optimal when consideration is given to the varying day and night conditions under which the panels will be used. Certain type faces used in the printing industry are cited as being most representative of the recommended ratio."

246. Shielding Device for Protection of Landing Signal Officer's Eyes Against Ultra-Violet Light.

Edward A. Lowery.

U. S. Aeronautical Medical Equipment Laboratory, Naval Air Experimental Station, Naval Air Material Center, Philadelphia, Pennsylvania.

Report TED No. NAM AE 25790, 26 September 1949, 8 pp., (0)

"The eyes of Landing Signal Officers must be protected from the radiation coming from the ultra-violet lamps used for activating the fluorescent strips of his garment during night carrier operations. A shield meeting the stated requirements, designated the NAES ISO eye shield, has been designed, fabricated, and

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evaluated. It is constructed of rubber laminated on an aluminum ribbing and is provided with elastic straps for positioning against the face. Satisfactory evaluations have been conducted under conditions of operational use."

247. Study of Exterior Lighting for Navy Airplanes - Field Observation by Composite Squadron Four

U. S. Bureau of Aeronautics, Naval Air Material Center, Naval Air Experimental Station, Aero. Medical Equipment Laboratory, Philadelphia, Pennsylvania.

Report TED No. NAM 31333, Topical Report XG-T-119, 8 May 1945, 7 pp., (0)

"Thirty-five (35) pilots attached to Composite Squadron Four (VC-4), observed experimental lighting installations on the SNJ-6 aircraft. Opinions obtained by use of a rating-scale questionnaire showed that the pilots strongly favored the flashing system of lights recommended for solo cross country flights, but preferred the wing tip running lights to remain steady for taxi. The use of coded section lights for rendezvous and join-up was also endorsed with consideration invited to the use of amber filters on these lights in place of the clear glass presently used. Primary attention of the observers was directed toward methods of lighting for formation flying and the pilots strongly favored linear wing trailing edge lights to replace the present standard formation lights. In conjunction with these lights, the linear tail light was preferred by twenty-eight (28) of the pilots over the use of floodlights on the vertical tail surface preferred by the other seven (7)."

248. Study of Exterior Lighting for Navy Airplanes. Report No. 5 on The Illumination of Lights on the Trailing Edge of Wings for Low Level Illumination of Aircraft.

Irene C. Blasdel, and Lazo, John.

U. S. Bureau of Aeronautics, Aeronautical Medical Equipment Laboratory, Naval Air Experimental Station, Naval Air Material Center, Philadelphia, Pennsylvania.

Report TED No. NAM 31333, 31 May 1949, 10 pp., (0)

"The report deals with the method in which four linear lights have been mounted on the trailing edges of the wings of an SNJ aircraft to produce low level illumination for night formation flying. This method of installation was effected by mounting fixture AN3091-3, within a surface covered by sanded acrylic plastic to produce linear illumination at the trailing edge wing tip and directly inboard from the wing tip on the fuselage. This type of installation interferes in no way with the flight characteristics of the SNJ aircraft used in this evaluation because it is integral with the contour of the aircraft. This is aerodynamically satisfactory for high speed aircraft and has the added distinct advantage of producing linear light rather than the illumination by point sources found in the present formation lights. Although the glowing lines of light produced are small in area, they furnish a comfortable visual reference and aid the pilot in maintaining position during night formation flying. The strip of light on the wing tip indicates any change in attitude of the wings, while the inboard strip, parallel to the line of normal flight of the aircraft, produces an immediate reference for climb and dive, and is useful for cross-under procedures.

"These linear formation lights are color coded to conform with international practice for navigation lights. The port wing strip is red, starboard wing green and both inboard lights are amber. All lights are equated in brightness and are operated at a sufficiently low level to be visible only within 700 feet.

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"The results of night flight evaluations on SNJ aircraft equipped with these and other experimental methods of exterior lighting will be the subject of subsequent reports."

249. Study of Exterior Lighting for Naval Airplanes. Report No. 6 on Night Flight Tests of Experimental Exterior Lighting Systems on Military Aircraft.

Irene C. Blasdel, and Lazo, John.

U. S. Bureau of Aeronautics, Aeronautical Medical Equipment Laboratory, Naval Air Experimental Station, Naval Air Material Center, Philadelphia, Pennsylvania.

Report TED No. NAM 31333, 1 June 1949, 39 pp., (0)

"Extensive flight tests have been conducted using experienced pilots observing SNJ aircraft equipped with standard and experimental methods of exterior lighting. The installations used on these aircraft and some of the flight tests have been previously reported, however this report summarizes all work accomplished to the present time.

"Flight tests discussed include those held at Eglin Field, Florida in conjunction with the Air Force lighting evaluations; at Boca Chica, Florida, by the Night Composite Squadron Two; and locally at Mustin Field, Philadelphia, by pilots attached to the Naval Air Experimental Station.

"As a result of all considerations of the problems encountered in night flying, it is now possible to formulate some definite conclusions concerning illumination for night operation of aircraft. Inasmuch as flashing of lights eliminates most of the confusion of aircraft lights with stars and ground lights, this method is suitable for taxi and solo cross-country flying. When planes are in formation, however, flashing causes confusion and disorientation to pilots of the formation, so that dim steady lights are required. The formation is distinctive against backgrounds of stars and ground lights when viewed from other aircraft because of the quantity of lights apparent during approach. When section lights are coded for signalling purposes, it is essential that all other lights on the aircraft be steady so that no confusion arises in the code.

"Although the collected data does not show absolute agreement on all observations, as a result of a study of the interpretation of any discrepancies and an intelligent consideration of the basic elements concerned in the lighting of aircraft, the following patterns are now recommended for military aircraft in accordance with the phase of flight operation encountered:

1. Taxi and solo cross country - The red port wing tip running light and the white tail light are flashed together in alternate phase with the green starboard wing tip running light and the amber tail light. The 6 candlepower section lights remain steady.
2. Signalling - Both red and green wing tip running lights and the white tail light remain steady while the 80 chandlepower section lights signal with any pre-set code.
3. Join-up - Both red and green wing tip running lights, wing trailing edge linear lights, and floodlighting of the vertical tail surface remain steady, together with the 6 candlepower section lights flashing a pre-set code.
4. Formation, medium bright - Both wing tip running lights, wing trailing edge

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linear lights and flood lighting of the vertical tail surface, all steady.

5. Formation, dim - Same lights as at the medium setting only at a very low level of brightness.

"All lighting installations mentioned in the above patterns are in accord with current specifications by the Bureau of Aeronautics with two exceptions, namely:

(1) The wing trailing edge linear lights are not presently specified, however, it is understood that the formation light specifications are currently being revised to include this type of installation.

(2) Although floodlighting the tail surfaces is specified and is listed above, an alternate method of illuminating this area by the use of plastic strips on the elevators and rudder is suggested particularly for aircraft used in primary night flight training.

"In order to facilitate the problem of controlling the exterior lighting of his aircraft by the pilot, a single switch system control is desirable. The possibility for pilot error is reduced and standardization of lighting more assured by such an arrangement. A suggested method of accomplishing this control is included in this report.

"In accordance with the details contained in this report, it is recommended that:

1. Specification drawing number R-203 for the spacing of the dual tail light be revised to include a wider spacing of these two fixtures. On SNJ aircraft, 6" spacing has been found optimal and superior to any closer spacing when the two lights are flashing.
2. Specifications for the existing flush mounted formation lights be replaced by specifications for small lights (AN3091) mounted within plastic covers, one at the trailing edge of each wing tip and one directly inboard on each side of the fuselage or at the wing root.
3. Existing specifications for floodlighting the vertical tail surfaces be continued until a more effective system may be developed and validated.
4. Specifications be issued for a simplified pilot control system for exterior lighting in accordance with the foregoing systems outlined for each maneuver.
5. Investigation of further methods of translucent surface illumination of vertical tail areas to be continued.
6. A series of tests on the exterior lighting of multi-engine aircraft be initiated to determine the suitability of the present recommended lighting systems for this type of aircraft.
7. Studies of exterior lighting should be directed toward the problems encountered by high performance aircraft."

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250. Effects of Benzedrine Sulphate on a Visual Vigilance Test.

N. H. Mackworth, and Winson, F. H.

Great Britain, Medical Research Council, Royal Naval Personnel Research Committee, Applied Psychology Research Unit, Psychological Laboratory, Cambridge.

R. N. P. 47/401, O.E.S. 129, A.P.U. 72., September, 1947, 9 pp. (0)

"Prolonged vigilance during a visual search task is known to lead to a reduction in the accuracy with which visual stimuli are detected (Anderson 1944, Mackworth 1944). There are several ways in which this decline can be prevented, notably by limiting the length of lookout watches to half an hour. But it was interesting to discover whether this falling-off in efficiency could be prevented by the use of Benzedrine Sulphate. It was found that a moderate dose of 10 mgms. Benzedrine Sulphate successfully maintained the initial level of accuracy over the whole of the two-hour test. This was a psychopharmacological result and was not due to any possible suggestion effects of the subject knowing that he had taken some tablets which might be affecting his efficiency.

"The same 24 subjects missed more than twice as many signals without Benzedrine (16%) as they did when they had been benzedrinized (7%). Four-fifths of the men made fewer errors with Benzedrine than without. On speed of response the men were very slightly quicker with Benzedrine, the average advantage being about one-fifth of a second.

"Only one of the 24 men had any unpleasant side effects during the test periods and complained of slight giddiness after Benzedrine. But no "hangover" effect could be found in the performance scores.

"It is not known whether these results are found when the substance is given repeatedly and there are also good reasons why Benzedrine should not be used in practice except with the very greatest of care."

251. The Threshold for Sudden Changes in the Velocity of a Seen Object.

W. E. Hick

Great Britain, Medical Research Council, Unit of Applied Psychology, the University Cambridge.

MRC 48/472, APU 88, September, 1948, 10 pp. (0)

"It is shown that the difference threshold for the velocity of a seen object obeys Weber's Law approximately, the divergence from the law appearing, in most cases, as an increase of the threshold at both ends of the range of initial speeds.

"The Mean Threshold (50 per cent probability of perception) varies between 7 and 22 per cent. The average value, in favourable conditions, is of the order of 12 per cent of the initial velocity.

"No certain difference was found between increases and decreases of velocity.

"When two moving objects, which converge, cross, and then diverge, are used, there is some tendency for the threshold to be higher; the difference is thought to be due to the confusing effect of the two objects.

"Velocity changes down to 2.5 per cent gave a significantly large proportion of correct responses, as compared with the responses to blank stimuli. The question of whether a definitely imperceptible stimulus can be found by the forced-guessing method is discussed.

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"Responses to blank stimuli showed a strong overall tendency to guess "slower". But the tendency differed significantly in degree between most of the experimental conditions.

"Reaction times showed the normal tendency to be greater, the less obvious the stimulus.

"Some evidence was obtained on the effect of reducing the exposure time. It appeared that exposures down to 0.5 second (the velocity change occurring in the middle of the exposure period) had little, if any, detrimental effect."

252. The Effect of Certain Operating Conditions on the Visibility of P.P.I. Radar Echoes.

K. J. W. Craik, and Macpherson, S. J.

Great Britain, Medical Research Council, Unit of Applied Psychology,
The University, Cambridge.

MRC 48/25, APU. 16, November 3, 1945, 7 pp. (0)

"Using synthetic electronic equipment in which an artificial "echo" is injected against a background of thermal noise into a P.P.I. display, the following conditions were investigated for their effect on echo-visibility:-

- (1) Effect of distance of eyes from screen;
- (2) Effect of external illumination falling on the tube-face;
- (3) Effect of Admiralty pattern illuminated scales, with amber filters;
- (4) Effect of amber filters alone, with complex or simple range and bearing grids;
- (5) Effect of duration of watch-period (being separately reported in conjunction with an investigation by Dr. N. H. Mackworth);
- (6) Effect of pulse-width on visibility;
- (7) Effect of angular distance of echo from line of sight of operator.

"The conclusions are:-

"1. The echo-visibility is not significantly different at 10, 18 and 30 inches head-distance, but there is a slight optimum at 18 inches. Since prolonged watching at a closer distance than this is liable to produce convergence and accommodation eye-strain in normal sighted operators they should be encouraged not to come closer than about 15 inches from the tube, since they will not in fact be able to detect the echoes any better by doing so.

"2. Illuminations of 0.1, 0.01, and 0.001 foot-candles on the tube face from extraneous light do not have any significantly different effects on echo-visibility at both 4 and 60 r.p.m. of scan; 1 foot candle, however, gives significantly poorer visibility (about 2db. loss). There is a slight optimum performance at 0.01 f.c. and it therefore seems unnecessary, and if anything slightly harmful, to keep P.P.I. offices completely darkened. Complete darkness also has other disadvantages mentioned in a previous report on A-Scope operation, viz: delay while operators become dark-adapted enough to see the trace at the very low brightness to which the previous dark-adapted operator may have set it, or alternatively continual and distracting readjustment of trace-brightness as dark-adaptation proceeds; also unnecessary difficulty in finding one's way about in the office and excluding light from a plotting table.

"3. The existing Admiralty pattern scales, with an imitation of the standard

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illuminating system, did not impair echo-visibility when the illumination on the scales was approximately 0.01 f.c. It was however, necessary to use the standard amber filters in conjunction with this lighting system, to avoid reflections in the tube-face, and one of the types of filter alone (i.e. without scale-lighting) slightly impaired echo-visibility, possibly because of its optical imperfections and the complicated range and bearing grid engraved on it. Thus the effect of the amber filters in reducing the bright blue "flash" of the trace did not improve echo-visibility. This suggests that a better solution would be a system of scale lighting (e.g. edge-lighting) which did not necessitate an amber filter to reduce reflections, though the present system does not appear to have measurable ill-effects.

"4. A brief investigation of pulse-widths from 1 to 4 microseconds showed a gain of approximately 3 db for each doubling of pulse-width.

"5. As a preliminary to a study of methods of visually scanning the tube-face, the decrease of echo-visibility with the angular distance between the operator's line of sight and the line joining the echo to his eye was measured and found to be about 2 db at 5° , 4 db at 10° and 8 db at 15° from his line of sight."

253. A Study of the Involuntary Blink Rate During Prolonged Visual Search.

A. Carpenter, M.B.

Great Britain, Medical Research Council, Unit of Applied Psychology,
The University, Cambridge.

MRC 48/49, APU. 21, July, 1945, 8 pp. (0)

"1. In 151 missed stimuli no case of the coincidence of a blink with a missed stimulus was seen.

"2. (a) There was a statistically significant increase in the average rate of blinking between the first and second half hours, with a further non-significant increase towards the end of the two hour test.

(b) There was evidence in some cases of an increase in the amplitude of the blinks as the test proceeded. It was not possible to study this quantitatively.

"3. Although cases of staring followed by a "burst" of blinking did occur, clear cut examples of this were rare, and there was no clear line of separation of these from the bulk of the records.

"Most of the subjects, however, showed considerable variability of the blink rate from minute to minute. This may indicate an instability of the mechanism of blinking of the same nature, but perhaps less extreme than would be indicated by alternate periods of staring and blinking.

"4. Besides this minute to minute variation in rate in the same subject, the mean blink rate showed wide variation from subject to subject."

254. Effects of Head and High Humidity on Prolonged Visual Search as Measured by the Clock Test.

N. H. Mackworth.

Great Britain, FPRC, Medical Research Council, Unit of Applied Psychology,
The University, Cambridge.

FPRC 386 (c), February, 1946, 16 pp. (0)

"PROBLEMS

"1. Do hot and moist atmospheres affect the accuracy with which faint visual

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signals are detected in a relatively monotonous situation?

"2. Is there any loss of alertness as shown by speed of response to the signals that are seen?

"3. If any performance deterioration is found, how far may the atmospheric temperature be allowed to rise (above the lowest temperature readily obtainable with air-conditioning plant in tropical waters) before this deterioration becomes statistically definite?

"4. Does increased room temperature lead to a rise in body temperature with sedentary work?

"5. Are the body temperature readings statistically related to the results on the clock test?

"6. If so, is there any evidence that a rise in body temperature causes deterioration in ability?

"MAIN FINDINGS.

"1. Hot and moist atmospheres undoubtedly impair the accuracy with which faint visual signals are detected in a relatively monotonous situation.

"2. Responses do tend to become rather sluggish - but this deterioration is not so marked as the decline in the accuracy of work.

"3. Within the range of temperatures likely to be found in the Tropics in ships with or without air-conditioning equipment, the optimum temperature for accurate visual search is an effective temperature of 79°F. for men acclimatized to high atmospheric temperatures and dressed only in shorts. This consists of a wet bulb reading of 75°F. and a dry bulb reading of 85°F. with an air velocity of 100 feet per minute. Performance deterioration becomes statistically definite on the clock test when the wet bulb reading is 85°F. and the dry bulb is 95°F. with an air velocity of 100 feet per minute. This is identical with the critical temperature found with the W. T. reception tests, and just two degrees above that obtained with the heavy pursuitmeter investigations.

"4. There is a weakly positive association between the final rectal temperature and the incidence of missed signals during the second hour of the test, but this relationship is not statistically reliable.

"5. A rise in body temperature does not cause deterioration in ability on the clock test."

255. Some Statistical Remarks on the Method of Constant Stimulus Differences.
Hermann von Schelling, Ph.D.
U. S. Submarine Base, Medical Research Laboratory, New London, Conn.
Project NM 003-02D, February 12, 1948, 7 pp. (0)

The author calls attention to the mathematical procedure utilized in analyzing psychophysical data known as the probit analysis. The method was developed by Fisher and his associates and is reported in "Probit Analysis", by D. J. Finney (1947). von Schelling discusses the mathematical advantages of the probit analysis as compared with the Müller-Urban constant process. He presents an argument in

favor of omitting the so-called "Müller-Urban weights" when using the probit analysis. An example of the use of the method is given utilizing data on auditory loudness discrimination.

256. A Battery of Pass-Fail Tests for Detecting Degree of Color Deficiency.
 Lt. Comdr. Dean Farnsworth, Sperling, Harry G., Kimble, Priscilla F.
 U. S. Naval Submarine Base, Medical Research Laboratory, New London, Conn.
 MRL Report No. 147, Vol. 8, pp. 39-68, 1949 (0)

"1. Seven tests of color vision were administered to 1440 young males, representing an unselected sampling of the State of Connecticut.

"2. All 1440 men were screened with 14 A.O. Plates, First Edition, and the Dimmick Anomaloscope. Deviants were examined as follows:

"One additional Dimmick setting, 14 A.O. Plates selected from the Second Edition, the Anomalight, the Navy Lantern and the Farnsworth Dichotomous B-20 and F-20 Dichotomous tests. The A.O. Plates and Dichotomous tests were administered under Macbeth Illuminant C artificial daylight.

"3. 141 men of 1440 screened proved color anomalous, comprising 9.79% of the sample examined. The plates alone failed 140 men (9.71%).

"4. There were 94 deutans (6.5%) and 47 protans (3.3%).

"5. 72 men were separated into deutan-protan types by both Dichotomous tests with no disagreements. 75 men were identified by Dichotomous tests and the Anomalight with one disagreement. The Anomalight and Dichotomous tests, it was concluded, are valid as deutan-protan classifiers. The Dimmick Anomaloscope disagrees 12 times with the other tests showing poor validity as a deutan-protan classifier.

"6. The relative stringency of the A.O. Plates plus the Dimmick, the Navy Lantern and the B-20 and F-20 Dichotomous tests was evaluated in terms of the proportion of the total anomalous that they failed. Those failed by A.O. plus Dimmick were called 100%. The Navy Lantern failed 80.1% of these, the B-20 64.3%, the F-20, 56.6%. It was shown that the A.O. plus Dimmick is significantly more stringent than the Navy Lantern which is significantly more stringent than the B-20. The B-20 and F-20 do not differ significantly.

"7. There was but one instance of reversal for all tests, indicating excellent internal validity. It is demonstrated that the validity for testing color vision is high for the A.O. plus Dimmick, the Navy Lantern and the Dichotomous tests.

"8. Test-retest data were reported for the Dimmick Anomaloscope, the Navy Lantern and the D-15 Dichotomous Test. All three indicated good reliability.

"9. A test battery employing selected A.O. Plates plus the Double Wedge Anomaloscope, the Navy Lantern, the Farnsworth Dichotomous D-15 and the Nagel Anomaloscope were recommended as classifying severity of defect into five classes.

- Class I - Normals (fail no tests)
- Class II - Mildly anomalous (fail Pseudo-Isochromatic Plates or Anomaloscope)
- Class III - Moderately Anomalous (fail Navy-type lantern)
- Class IV - Severely Anomalous (fail F-20 Dichotomous Test)
- Class V - Dichromatic (match entire range on the Nagel Anomaloscope).

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"10. It was found that roughly 2% to 2.5% of all men fail in each anomalous class.

"11. The present data were discussed with relation to four other large sample surveys with reference to the higher incidence of anomaly found here. The possibility of explaining the discrepancy in terms of the ethnic composition of the samples studied and in terms of the standardization of illumination was evaluated."

257. A Method for Calculating the Effect of Filters on Color Vision.

Hermann von Schelling, Ph.D.

U. S. Naval Submarine Base, Medical Research Laboratory, New London, Conn.

MRL Report No. 148, Vol. 8, pp. 69-83, 1949 (0)

"The purpose of this paper is to calculate specimen curves which indicate in general how colors shift if a filter is applied. The first section contains the mathematical formulae. The method is used for studying the absorption by the macular pigment (Sect. II) and by the intraocular media (Sect. III). The last example (Sect. IV) refers to the change in illumination from illuminant C to illuminant A and inversely."

258. The Effect of Low Color Temperature Illumination and Red Illumination Upon Subsequent Dark Adaptation.

R. T. Mitchell

U. S. Naval Submarine Base, Medical Research Laboratory, New London, Conn.

MRL Report No. 146, Vol. 8, pp. 27-38, 1949 (0)

"The relative effect of red illumination and low color temperature illumination upon subsequent dark adaptation was experimentally determined.

"Measurements were made following 20 minutes adaptation to four conditions:

- A. 6.0 ft-L at 2800°K
- B. 0.40 ft-L at 2800°K
- C. 0.40 ft-L at 1950°K (reduced voltage)
- D. Red goggles worn in 6.0 ft-L at 2800°K.

Three complete adaptation curves for one observer were taken for each condition. Evaluation was made in terms of mean time required to reach a given threshold.

"Low color temperature adaptation was found definitely inferior to red light in inducing dark adaptation. The psychophysiological basis of this phenomenon is briefly discussed.

"Secondarily it was noted that it was necessary to increase lighting units and current consumption in order to equate the brightness of a low voltage source to the brightness of a red filtered bulb of the same wattage at normal voltage."